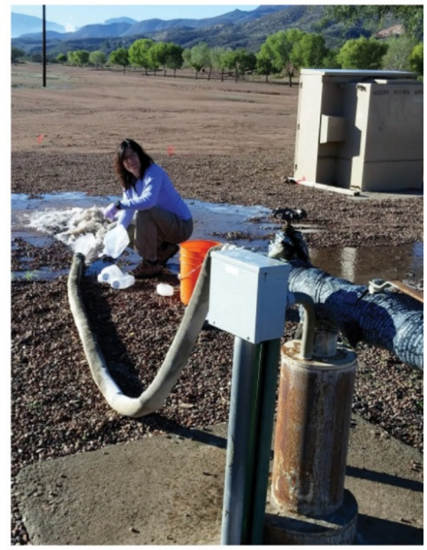
Arizona Department of Environmental Quality

Ambient Groundwater Quality of the Salt River Basin



A 2001-2015 Baseline Study
June 2016

Arizona Department of Environmental Quality
Water Quality Division
Surface Water Section Monitoring Unit
1110 West Washington Street
Phoenix, AZ 85007-2935

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Ambient Groundwater Quality of the Salt River Basin: A 2001-2015 Baseline Study

By Douglas C. Towne

Arizona Department of Environmental Quality
Open File Report 16-01

ADEQ Water Quality Division
Surface Water Section
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1110 West Washington St.
Phoenix, Arizona 85007-2935

Thanks:

Field Assistance:	Elizabeth Boettcher, Joe Harmon, Angela Lucci, Greg Olsen, and Patti Spindler. Special recognition is extended to the many well owners who gave their permission to collect groundwater data on their property.
Photo Credits:	Douglas Towne
Report Cover:	ADEQ's Elizabeth Boettcher collects a sample from Crescent Spring, the flow of which contributes to Crescent Lake in the background. Lab analysis revealed the water had a very low salt and mineral content.

ADEQ Ambient Groundwater Quality Open-File Reports (OFR) and Factsheets (FS):

Gila Bend Basin	OFR 15-07 77 p.	FS 15-05, 6 p.
Tiger Wash Basin	OFR 14-07, 33 p.	FS 14-20, 4 p.
Avra Valley Sub-basin of the Tucson AMA	OFR 14-06, 63 p.	FS 14-11, 5 p.
Harquahala Basin	OFR 14-04, 62 p.	FS 14-09, 5 p.
Tonto Creek Basin	OFR 13-04, 50 p.	FS 13-18, 4 p.
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Hualapai Valley Basin	OFR 07-05, 53 p.	FS 07-10, 4 p.
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Prescott Active Management Area	OFR 00-01, 77 p.	FS 00-13, 4 p.
Upper San Pedro Basin (w/ USGS)	OFR 99-12, 50 p.	FS 97-08, 2 p.
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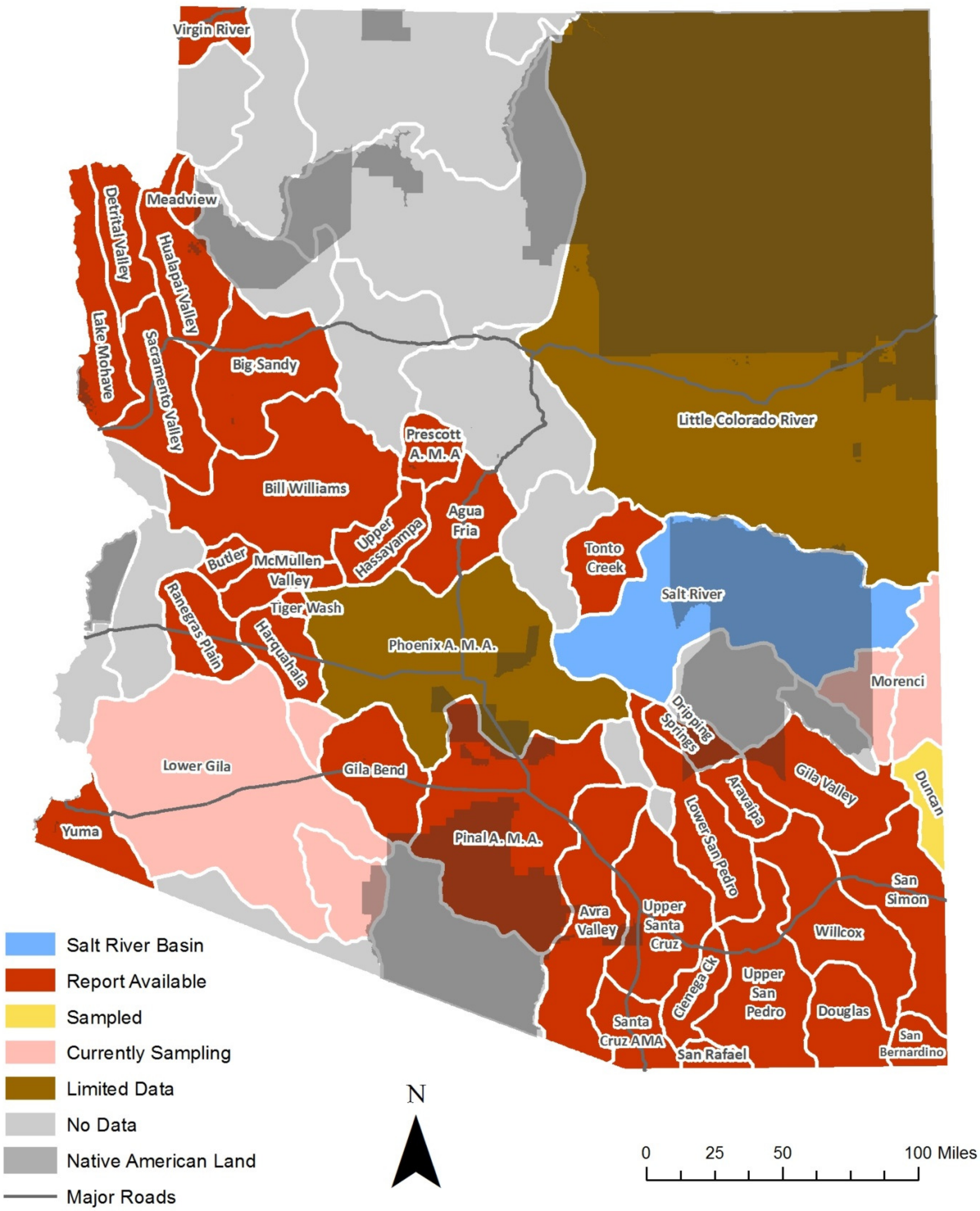
ADEQ Ambient Groundwater Reports



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Abbreviations

amsl	above mean sea level
ac-ft	acre-feet
af/yr	acre-feet per year
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ADWR	Arizona Department of Water Resources
AMA	Active Management Area
ARRA	Arizona Radiation Regulatory Agency
AZGS	Arizona Geological Survey
As	arsenic
bls	below land surface
BLM	U.S. Department of the Interior Bureau of Land Management
^oC	degrees Celsius
$CI_{0.95}$	95 percent Confidence Interval
Cl	chloride
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
gpm	gallons per minute
HCl	hydrochloric acid
LLD	Lower Limit of Detection
Mn	manganese
MCL	Maximum Contaminant Level
ml	milliliter
msl	mean sea level
ug/L	micrograms per liter
um	micron
µS/cm	microsiemens per centimeter at 25° Celsius
mg/L	milligrams per liter
MRL	Minimum Reporting Level
ns	not significant
ntu	nephelometric turbidity unit
pCi/L	picocuries per liter
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
SAR	Sodium Adsorption Ratio
SDW	Safe Drinking Water
SC	Specific Conductivity
SRB	Salt River Basin
su	standard pH units
SO_4	sulfate
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VOC	Volatile Organic Compound
WQARF	Water Quality Assurance Revolving Fund
*	significant at $p \leq 0.05$ or 95% confidence level
**	significant at $p \leq 0.01$ or 99% confidence level

Abstract

The Arizona Department of Environmental Quality (ADEQ) conducted a baseline groundwater quality study of the Salt River basin located in east-central Arizona. Sampling was done in two stages: from 2001-2002, and 2014-2015. The basin comprises 5,232 square miles within Apache, Gila, Greenlee, Maricopa, and Navajo counties and consists of mountains, plateaus, and canyons.[1]

Land ownership consists of tribal lands (59.4 percent) of the White Mountain Apache and the San Carlos Apache nation, federal lands (38.6 percent) managed by the U.S. Forest Service, and private lands (1.5 percent).[2] The basin's population was 29,057 in 2000, most of who lived in the communities of Globe, Miami, Young, and in White Mountain Apache nation communities of Fort Apache and Whiteriver.[3] The major land uses are for recreation and livestock grazing and mining in the Globe-Miami area.

The basin is composed of four sub-basins and is drained by the Salt River, a perennial stream that is formed at the confluence of the Black and White Rivers. The Salt River is impounded at four dams within the Tonto National Forest forming four lakes: Theodore Roosevelt, Apache, Canyon, and Saguaro.

ADEQ sampled 75 sites (45 wells and 30 springs), which were divided into the following sub-basins: Black River (19), White River (0), Salt River Canyon (17), and Salt River Lakes (39). Inorganic constituents were collected at every site while other samples were collected at selected sites: radionuclides (52) oxygen, deuterium, and nitrogen isotopes (36), volatile organic compounds or VOCs (20), and radon (13).

Based on sample results, groundwater in the basin is generally suitable for drinking water uses. Of the 75 sites sampled, 43 (57 percent) met all drinking water quality standards. Groundwater is commonly calcium-bicarbonate chemistry, slightly-alkaline, fresh, with varying hardness levels.[4, 5]

Health-based, Primary Maximum Contaminant Levels (MCLs) were exceeded at 13 sites (17 percent) and include arsenic (eight sites), gross alpha (four sites), uranium (three sites), and fluoride (one site). These are enforceable standards for drinking water purposes supplied by a public water system, and are based on a lifetime daily consumption of two liters.[6]

Aesthetics-based Secondary MCL water quality guidelines were exceeded at 27 sites (36 percent). Constituents above Secondary MCLs include total dissolved solids (TDS) (14 sites), iron (six sites), manganese (five sites), pH-field and aluminum (four sites), chloride (three sites), sulfate and fluoride (two sites), and zinc (1 site).

Most groundwater constituent concentrations significantly differed by sub-basins, with concentrations increasing downgradient in elevation (Kruskal-Wallis with Tukey test, $p \leq 0.05$). Depending on the constituent, the middle Salt River Canyon sub-basin had concentrations that were similar to either the up-gradient Black River sub-basin or the downgradient Salt River Lakes sub-basin.

The majority of the White River sub-basin is on tribal lands and no sites were sampled. Based on patterns revealed in this study, however, the constituent concentrations are likely between those found in the up-gradient Black River sub-basin and the downgradient Salt River Canyon and Salt River Lakes sub-basins.

Introduction

Purpose and Scope

The Salt River basin comprises 5,232 square miles within east-central Arizona and includes portions of Apache, Gila, Greenlee, Maricopa, and Navajo counties (Figure 1).[7] The basin extends from the White Mountains located near the New Mexico border to northeast of Phoenix at Stewart Mountain Dam at Saguaro Lake.

The basin's population was 29,057 in 2000, most of who lived in the communities of Globe, Miami, Young, and in Fort Apache and Whiteriver on the White Mountain Apache nation.[8] Most land is used for recreation and livestock grazing, with major copper mines in the Globe-Miami area.

The basin is physically characterized by mid-to-high elevation mountain ranges, plateaus, and canyons. Groundwater is predominantly pumped for mining purposes with minor amounts used for public water, domestic, irrigation, and stock uses.

Sampling by the Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring program is authorized by legislative mandate in the Arizona Revised Statutes §49-225.

The specific citation is "*…ongoing monitoring of waters of the state, including…aquifers to detect the presence of new and existing pollutants, determine compliance with applicable water quality standards, determine the effectiveness of best management practices, evaluate the effects of pollutants on public health or the environment, and determine water quality trends*."[9]

Benefits of Study

This study is designed to provide the following benefits:

- Characterizing regional groundwater quality conditions in the Salt River basin.
- Identifying significant water quality differences among groundwater sub-basins.
- Investigating potential groundwater quality impacts arising from mineralization, mining, irrigation, livestock, septic tanks, and/or improper well construction.
- Identifying further groundwater quality research needs.

Physical and Cultural Resources

Geography

The Salt River basin is located within the Central highlands physiographic province, a transitional area separating the Colorado Plateau to the north and the Basin and Range province to the south. Much of the basin's northern boundary is formed by the Mogollon Rim, a 2,000-foot escarpment. The basin is bounded on the west and southwest by the Sierra Ancha and Superstition mountains, on the south by the Nantac Rim, and on the east by the White Mountains (Figure 1).[10] Elevations range from Mount Baldy at 11,241 feet above mean sea level (amsl) in the White Mountains to approximately 1,500 feet amsl at Saguaro Lake.

Vegetation types in the basin include, with increasing elevation, Arizona upland Sonoran desert scrub; semi-desert, plains, and Great Basin and subalpine grasslands; interior chaparral; madrean evergreen woodland; Great Basin conifer woodland; and montane and Rocky Mountain subalpine conifer forests.

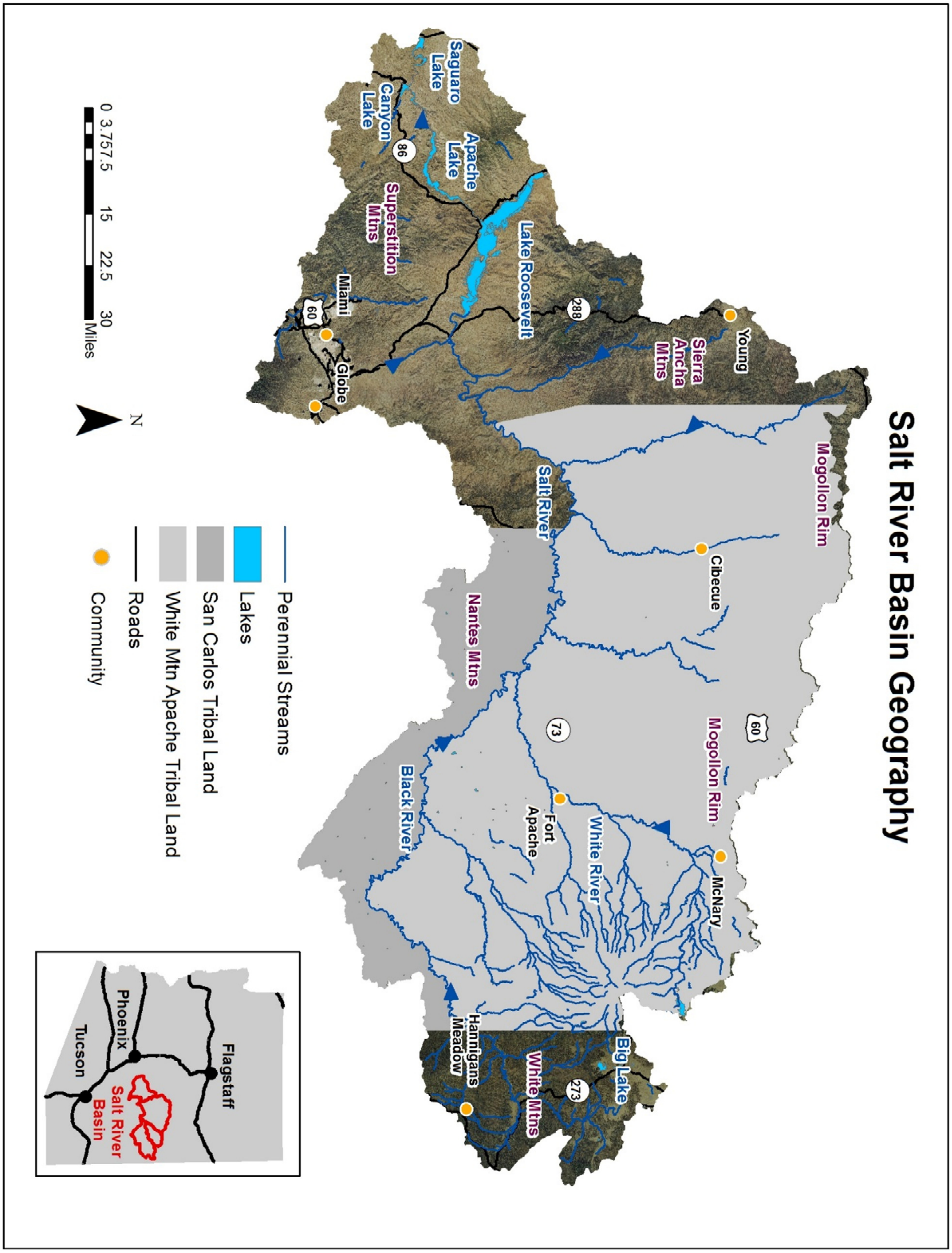


Figure 1 – Salt River Basin Geography

Figure 2 - ADEQ's Elizabeth Boettcher samples Spence Spring (SRB-43) located at the top of the basin in the Black Mountain sub-basin.

Riparian vegetation includes mesquite, mixed broadleaf and tamarisk along the Salt River, and mixed broadleaf along the Black River.[11]

Land Ownership

Land ownership consists of tribal lands of the White Mountain Apache and the San Carlos Apache nations, which compose 59.4 percent of the basin.

Federal lands managed by the U.S. Forest Service as part of the Tonto and Apache-Sitgreaves National Forests constitute 38.6 percent of the basin. Included in this category are five wilderness areas: the Salome Wilderness (18,515 acres), Sierra Ancha Wilderness (21,007 acres), much of the Superstition Wilderness (160,135 acres), Salt River Wilderness (32,088 acres), and a portion of the Bear Wallow Wilderness (11,336 acres).

Private lands compose 1.5 percent of the basin and are found in the Miami/Globe area and numerous in-holdings in the forest. The remainder (0.5 percent) consists of Bureau of Land Management, State Trust, National Park Service, and Arizona Game and Fish lands.[12]

Climate

The climate in the Salt River basin varies widely and is primarily a function of elevation. Precipitation averages up to 36 inches in the White Mountains, decreasing to less than 12 inches at Saguaro Lake.[13] Precipitation is heaviest in July and August with late summer thunderstorms. The winter months typically have moderate amounts of precipitation. These low-intensity winter storms provide more infiltration than the intense, monsoon thunderstorms that produce large amounts of runoff.

Surface Water Resources

The basin is drained by the Salt River, a perennial stream which runs east to west through the southern part of the basin. The Salt River is formed by the confluence of the White and Black rivers. The Salt River forms the boundary between the White Mountain Apache Tribe to the north and the San Carlos Apache Tribe to the south.

The Salt River is impounded at four dams within the Tonto National Forest starting with Theodore Roosevelt Dam, which forms the lake of the same name (Figure 3). Completed in 1911 and expanded in 1996, Theodore Roosevelt Lake has a storage capacity of 1,653,043 acre-feet.

Downgradient is Horse Mesa Dam, which forms Apache Lake. Completed in 1927, the lake has a storage capacity of 245,138 acre-feet. Mormon Flat Dam, which forms Canyon Lake, was completed in 1925 and holds 57,852 acre-feet of water. Furthest downgradient is Stewart Mountain Dam, which was completed in 1930. The reservoir formed by the dam, Saguaro Lake, has a storage capacity of 69,765 acre feet.[14]

Major tributaries to the Salt River within the basin include Cherry Creek, Canyon Creek, Cibecue Creek, Carrizo Creek, and Cedar Creek. The streams in the drier western portion of the basin are mainly intermittent. High-elevation lakes within the basin, in descending order of maximum storage, include Sunrise, Big, Reservation, Crescent, Horseshoe Cienega, Cyclone, and Hawley lakes in the White Mountains.[15]

Groundwater Resources

The Salt River basin is characterized by a relatively narrow band of rugged mountains composed of igneous, metamorphic, and sedimentary rocks (Figure 30). Groundwater flows from springs in the higher elevations, which supply perennial streams such as the Salt River which serves as a major water supply for the Phoenix metropolitan area. The basin has minimal water storage capabilities and high runoff because of the prevalence of bedrock and steep gradients. The groundwater resources depend on short-term recharge and are impacted by drought and well pumping.[16]

Major aquifers in the basin include recent stream alluvium, volcanic rock (the Pinetop-Lakeside Aquifer), and sedimentary rock (Gila Conglomerate; C and R aquifers). Well yields vary widely, ranging up to greater than 2,000 gallons per minute (gpm) based on 140 wells. Natural recharge to the basin is estimated at 178,000 acre-feet per year. There is an estimated 8.7 million acre-feet in storage to a depth of 1,200 feet in the basin.[17]

Figure 3 - Theodore Roosevelt Lake with the new highway bridge that was completed in 1996.

Figure 4 - A-1 Lake on Fort Apache Tribal lands.

The Salt River basin is divided, from east to west in a downgradient progression, into four sub-basins: Black River (Figure 4), White River, Salt River Canyon, and Salt River Lakes (Figure 2).

Black River Sub-basin

Volcanic rocks including basalt flows, rhyolitic ash flows, tuffs, and tuffaceous agglomerates form layers in excess of 3,000 feet thick in this sub-basin. Cinder beds, fracture zones, and weathered zones provide the best well yields to a limited numbers of stock and domestic wells, which average 400 to 800 feet in depth. The few wells in this sub-basin have not exhibited water-level declines indicating it maybe be at or near steady-state condition.[18]

White River Sub-basin

Like the Black River sub-basin, volcanic rocks such as basaltic lava flows, cinder beds, and tuffaceous agglomerates cover the eastern part of the sub-basin. In contrast, the southwestern part of the White River sub-basin consists of consolidated sedimentary rock. Groundwater is produced from springs and shallow, low-yield wells.

Basaltic rocks form an aquifer locally known as the Pinetop-Lakeside aquifer, which can produce more than 300 gallons per minute.[19] The vast majority of this sub-basin is located on tribal lands.

Salt River Canyon Sub-basin

Most of the sub-basin consists primarily of consolidated sedimentary rocks that extend into the White River sub-basin. The limestone, sandstone, siltstone, shales, and thin conglomerates have been eroded by the Salt River, which is the sub-basin's major drainage.

The western section of the sub-basin is composed of sedimentary and igneous granitic rocks. Only a few wells have been completed but springs have been measured at 900 gpm. Near the Salt River Canyon, upper rock units have been dewatered while lower units discharge groundwater to support the base flow of the Salt River.[20]

Salt River Lakes Sub-basin

The sub-basin contains mostly igneous, granitic, metamorphic, and sedimentary rocks with unconsolidated sediments in the larger valleys. Groundwater, in varying amounts, occurs in all these geologic units. The unconsolidated sands and gravel along stream floodplains are the most productive aquifer.

In the Globe-Miami area, these sediments along Pinal Creek are known as the Gila Conglomerate, which is up to 4,000 feet thick. This local aquifer provides water to mining and public supply wells in the area (Figure 9).

Figure 5 - ADEQ's Patti Spindler collects a sample (SRB-75) from Ferndell Spring near the summit of Pinal Peak south of Globe.

Elsewhere in the sub-basin, most groundwater production is limited to low-yield domestic and stock wells. Limestone rocks can also produce large amounts of water, especially where fractured and faulted. In contrast, because of their low permeability, igneous and granitic rocks provide minor amounts of water only where the geology is fractured, fissured, and faulted.[21]

Groundwater Characteristics

Limited groundwater quality sampling has been conducted in the Salt River basin. Almost all of the available data was collected in the extreme southwest of the basin, in the Salt River Lakes sub-basin near the Globe-Miami area.

Samples collected along the south side of Theodore Roosevelt Lake have occasional exceedances of arsenic, fluoride, and radionuclides. The majority of the groundwater samples are located near or downgradient of the large copper mines along Pinal Creek and are characterized by acidic water with heavy metal exceedances such as beryllium, cadmium, copper, chromium, and lead.[22]

Investigation Methods

ADEQ sampled 75 sites, 45 wells and 30 springs (Figure 5), to characterize the regional groundwater quality in the Salt River basin (Figure 6). The following types and numbers of samples were collected:

- Inorganic suites at 75 sites,
- Radionuclides at 52 sites,
- Oxygen, deuterium, and nitrogen isotopes at 36 sites,
- VOCs at 20 sites, and
- Radon at 11 sites.

The 75 samples collected for the study consisted of 45 wells and 30 springs. The wells were powered by submersible pumps (42) and windmills (3).

Each well was evaluated before sampling to determine if it met ADEQ requirements. A well was considered suitable for sampling when the following general conditions were met: the owner had given permission to sample, a sampling point existed near the wellhead, and the well casing and surface seal appeared to be intact and undamaged. [23]

Additional information on groundwater sample sites compiled from the Arizona Department of Water Resources (ADWR) well registry is available in the appendices.

Sample Collection

The sample collection methods for this study conformed to the Quality Assurance Project

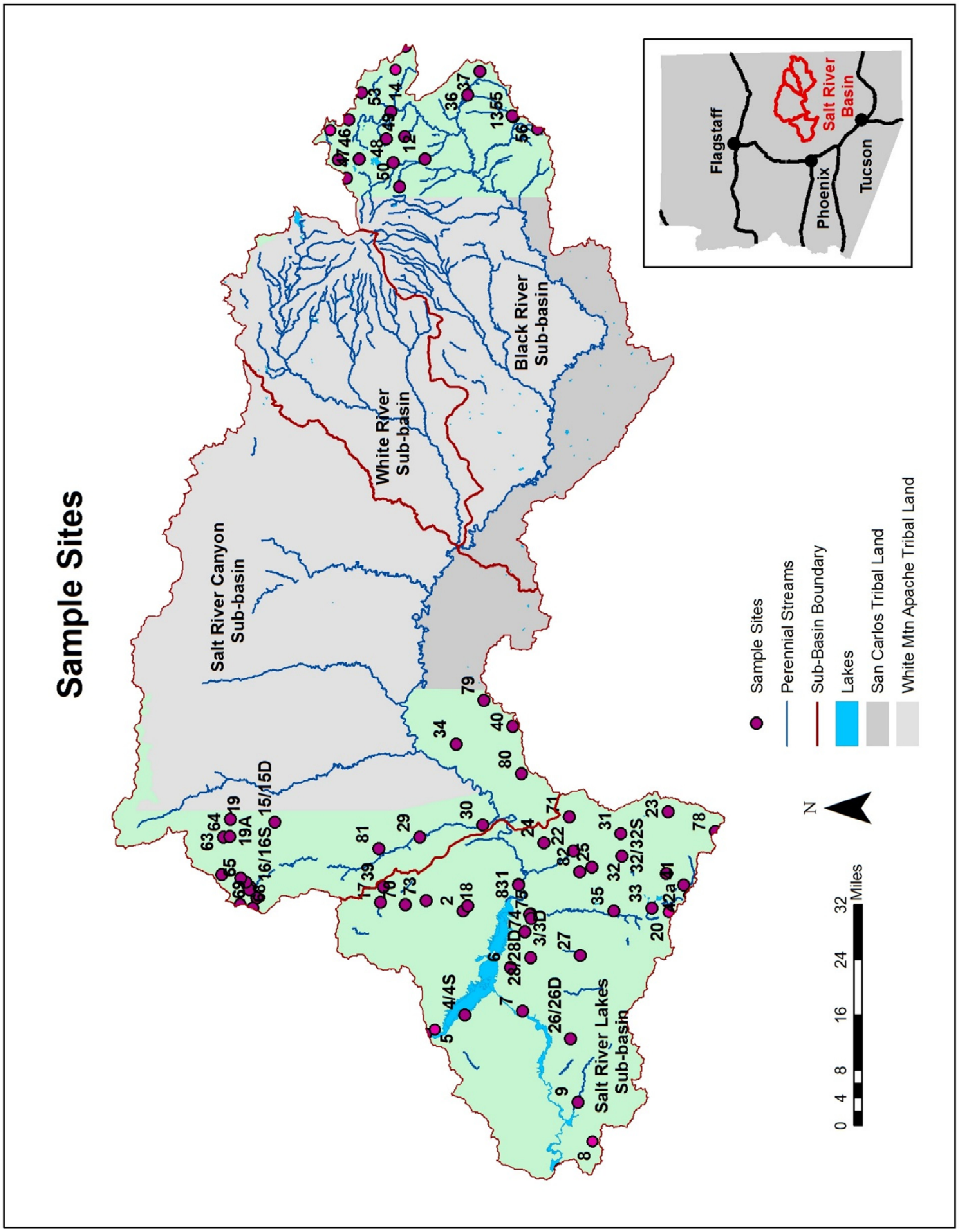


Figure 6 - Sample Sites.

Plan (QAPP) [24] and the Field Manual for Water Quality Sampling.[25] While these sources should be consulted as references to specific sampling questions, a brief synopsis of the sample collection procedures is provided.

After obtaining permission from the well owner, the volume of water needed to purge the well three bore-hole volumes was calculated from well log and on-site information. Physical parameters, temperature, pH, and specific conductivity (SC), were monitored approximately every five minutes using an YSI multi-parameter instrument (Figure 8).

To assure obtaining fresh water from the aquifer, after pumping three bore volumes and physical parameter measurements were stabilized within 10 percent, a sample representative of the aquifer was collected from a point as close to the wellhead as possible. In certain instances, it was not possible to purge three bore volumes. In these cases, at least one bore volume was evacuated and the physical parameters had stabilized within 10 percent.

Sample bottles were labeled with the Salt River basin prefix (SRB) and filled in the following order based on their volatility:

- VOCs
- Radon
- Inorganics
- Radionuclides
- Isotopes

VOC samples were collected in two, 40 milliliter (ml) amber glass vials which contained 10 drops 1:1 hydrochloric (HCl) acid preservative prepared by the laboratory. Before sealing the vials with Teflon caps, pH test strips were used to confirm the pH of the sample was below 2 su; additional HCl acid was added if necessary to lower the pH level. VOC samples were also checked to make sure there was no air in the vials.[26]

Radon, a naturally occurring, intermediate breakdown from the radioactive decay of uranium-238 to lead-206, was collected in two unpreserved, 40 ml clear glass vials. Radon samples were filled to minimize volatilization and sealed so that no headspace remained.[27]

The inorganic constituents were collected in three, one-liter polyethylene bottles. Samples to be analyzed for dissolved metals were filtered into a bottle using a positive-pressure filtering apparatus with a 0.45 micron (µm) pore size groundwater capsule filter and preserved with 5 ml nitric acid (70 percent). Samples to be analyzed for nutrients were preserved with 2 ml sulfuric acid (95.5 percent). Samples to be analyzed for other inorganic parameters were unpreserved.[28]

Radiochemistry samples were collected in a collapsible four-liter plastic container.[29]

Oxygen and hydrogen isotope samples were collected in a 250 ml polyethylene bottle with no preservative or refrigeration. Nitrogen isotope samples were collected in a 500 ml polyethylene bottle and filled ¾ full to allow room for expansion when frozen. [30]

All samples were kept at 4 degrees Celsius with ice in an insulated cooler, with the exception of the radionuclide, and oxygen and hydrogen isotope samples. Nitrogen samples were frozen and submitted to the laboratory.[31]

Chain of custody procedures were followed in sample handling. Samples for this study were collected during 14 field trips conducted between October 2001 and October 2015 (Figure 10).

Laboratory Methods

Inorganic analyses for the study were conducted by two laboratories.

The initial 40 inorganic samples (SRB-1 to SRB-42a) were analyzed by Arizona Department of Health Services (ADHS) Laboratory of Phoenix, Arizona. Inorganic analyses for the subsequent 36 samples (SRB-42b to SRB-83) were analyzed by the Accutest Northern California Laboratory in San Jose, California.

One site (SRB-16/59) was resampled with the original analysis conducted by the ADHS lab and the subsequent analysis performed by the Accutest laboratory.

A complete listing of inorganic parameters, including laboratory method and Minimum Reporting Level (MRL) for each laboratory is provided in Table 1 and Table 2. Inorganic sample splits, up to SRB-42a, were analyzed by Del Mar Laboratory (now Test America Laboratory) in Phoenix, Arizona. Inorganic sample splits, after SRB-42b, were analyzed by Test America Laboratory in Phoenix, Arizona.

Radionuclide analyses up to SRB-42a were conducted by Arizona Radiation Regulatory Agency (ARRA) in Phoenix, Arizona. Radionuclide analyses after SRB-44, and radon analyses, were conducted by the Radiation Safety Engineering, Inc. Laboratory in Chandler, Arizona.

Isotope samples were analyzed by the Laboratory of Isotope Geochemistry at the University of Arizona in Tucson, Arizona.

The VOC analyses were conducted by the Arizona Department of Health Services (ADHS) Laboratory in Phoenix, Arizona.

Figure 7 - ADEQ's Liz Boettcher samples Procopio Spring (SRB-73) located north of Globe near Richmond Mountain. The water was of mixed-bicarbonate chemistry and exceeded the TDS standard.

Table 1 - Laboratory Water Methods and Minimum Reporting Levels Used in the Study

Constituent	Instrumentation	ADHS / Accutest Water Method	ADHS / Accutest Minimum Reporting Level
Physical Parameters and General Mineral Characteristics			
Alkalinity	Electrometric Titration	SM 2320B	6 / 5
SC (µS/cm)	Electrometric	EPA 120.1 / SM 2510 B	2 / 1
Hardness	Calculation	SM 2340B / SW 846	13 / 33
pH (su)	Electrometric	EPA 150.1 / SM 4500H+	1.68 / -
TDS	Gravimetric	EPA 160.1 / SM 2540C	20 / 10
Turbidity (NTU)	Nephelometric	EPA 180.1 / SM 2130B	0.2 / 0.5
Major Ions			
Calcium	ICP-AES	EPA 200.7	2 / 5
Magnesium	ICP-AES	EPA 200.7	2 / 5
Sodium	ICP-AES	EPA 200.7 / EPA 200.8	2 / 10
Potassium	Flame AA	EPA 200.7 / EPA 200.8	2 / 0.5
Bicarbonate	Calculation	Calculation - SM 2320B	-
Carbonate	Calculation	Calculation - SM 2320B	-
Chloride	Potentiometric Titration	SM 4500CLD / EPA 300.0	20 / 50
Sulfate	Colorimetric	EPA 300.0	20 / 5
Nutrients			
Nitrate as N	Colorimetric	EPA 300.0	0.2 / 0.1
Nitrite as N	Colorimetric	EPA 353.2 / EPA 300.0	0.2 / 0.1
Ammonia	Colorimetric	EPA350.1 / SM 4500NH-3D	0.05 / 1.0
TKN	Colorimetric	EPA 351.2 / SM 4500	1.0 / 0.2
Total Phosphorus	Colorimetric	EPA 365.4 / SM 4500	0.1 / 0.02

All units mg/L unless noted otherwise

Table 2 - Laboratory Water Methods and Minimum Reporting Levels Used in the Study

Constituent	Instrumentation	ADHS / Accutest Water Method	ADHS/ Accutest Minimum Reporting Level
Trace Elements			
Aluminum	ICP-AES	EPA 200.7	0.2
Antimony	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.003 / 0.006
Arsenic	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.003 / 0.01
Barium	ICP-AES	EPA 200.7 / EPA 200.8	0.001 / 0.2
Beryllium	Graphite Furnace AA	EPA 200.9 / EPA 200.7	0.001 / 0.005
Boron	ICP-AES	EPA 200.7	0.2 / 0.1
Cadmium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.001 / 0.002
Chromium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.002 / 0.01
Copper	Graphite Furnace AA	EPA 200.7 / EPA 200.8	0.003 / 0.01
Fluoride	Ion Selective Electrode	SM 4500F-C / EPA 300.0	0.4 / 0.1
Iron	ICP-AES	EPA 200.7	0.1 / 0.2
Lead	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.001 / 0.01
Manganese	ICP-AES	EPA 200.7	0.01 / 0.015
Mercury	Cold Vapor AA	SM 3112B / EPA 245.1	0.0002
Nickel	ICP-AES	EPA 200.7	0.01 / 0.005
Selenium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.002 / 0.01
Silver	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.001 / 0.005
Strontium	ICP-AES	- / EPA 200.7	0.1 / 0.01
Thallium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.001 / 0.01
Zinc	ICP-AES	EPA 200.7	0.05 / 0.02
Radionuclides			
Gross alpha	Gas flow counter	EPA 600 / 00.02	varies
Radium 226	Gas flow counter	EPA 903.0	varies
Radium 228	Gas flow counter	EPA 904.0	varies
Radon	Liquid scantill. counter	EPA 913.1	varies
Uranium	ICP-AES	EPA 200.8	Varies

All units mg/L unless noted otherwise

Data Evaluation

Quality Assurance

Quality-assurance (QA) procedures were followed and quality-control (QC) samples were collected to quantify data bias and variability for the Salt River basin study. The design of the QA/QC plan was based on recommendations provided in the *Quality Assurance Project Plan* (*QAPP*)[32] and *the Field Manual for Water Quality Sampling*.[33]

The following types and numbers of QC inorganic samples collected for this study:

- one travel blank,
- one equipment blank,
- ten duplicate samples,
- seven split samples, and
- one well was sampled twice for time-trend data.

Blanks

One travel blank for inorganic analyses was collected for the study to ensure no contamination occurred during the field trip.[34]

The travel blank sample for major ion and nutrient analyses were collected by filling unpreserved bottles with de-ionized water. The nutrient bottle was subsequently preserved with sulfuric acid. The equipment blank sample for dissolved metal analysis was collected using de-ionized water that had been filtered into a bottle and preserved with nitric acid. All these procedures were done in the ADEQ laboratory and placed in the sample cooler before leaving on the field trip.

The travel blank was submitted to the ADHS laboratory (SRB-15B). Specific conductivity (SC) at 1.2 umhos/cm and turbidity at 0.09 NTU were the only constituents that were detected in the travel blank.

One equipment blank for inorganic analysis was collected for the study to ensure adequate decontamination of sampling equipment, and that the filter apparatus and/or de-ionized water were not impacting groundwater quality sampling.[35]

The equipment blank sample for major ion and nutrient analyses were collected by filling unpreserved bottles with de-ionized water. The nutrient bottle was subsequently preserved with sulfuric acid. The equipment blank sample for dissolved metal analysis was collected using de-ionized water that had been filtered into a bottle and preserved with nitric acid. The equipment blank was submitted to the Accutest laboratory (SRB-72). No constituents were detected in the equipment blank.

Figure 8 - ADEQ's Patti Spindler reads the physical parameters at Three Forks Spring (SRB-53) located in the Black River sub-basin.

Duplicate Samples

Duplicates are identical sets of samples collected from the same source at the same time and submitted to the same laboratory with different identification numbers, dates, and times. Data from duplicate samples provide a measure of variability from the combined effects of field and laboratory procedures.[36]

Duplicate samples were collected from sampling sites that were believed to have elevated or unique constituent concentrations as evaluated by SC and pH field values.

Ten duplicate samples were collected for this study. Eight duplicate samples were submitted to the ADHS laboratory and two duplicate samples to the Accutest laboratory. The analytical results were evaluated by examining the variability in constituent concentrations in terms of absolute levels and as the percent difference.

Analytical results from the ADHS laboratory duplicate samples indicate that of the 40 constituents examined, 22 had concentrations above the MRL. The duplicate samples had a maximum variation or percent difference between constituents less than or equal to 10 percent. Constituents exceeding this acceptable level include turbidity (12 percent) and total phosphorus (21 percent) (Table 3).

Four constituents were detected in only one of the duplicate samples near the MRL:

- Fluoride was detected in sample (SRB-37D) at a concentration of 0.21 mg/L and not detected in the duplicate (SRB-37) at an MRL of 0.20 mg/L.
- Total phosphorus was detected in sample (GIL-15) at a concentration of 0.36 mg/L and not detected in the duplicate (SRB-15D) at an MRL of 0.20 mg/L.
- Zinc was detected in sample (SRB-8) at a concentration of 0.054 mg/L and not detected in the duplicate (SRB-8D) at an MRL of 0.05 mg/L.
- Iron was detected in sample (SRB-8) at a concentration of 0.11 mg/L and not detected in the duplicate (SRB-8D) at an MRL of 0.10 mg/L.

Analytical results from the Accutest duplicate samples indicate that of the 40 constituents examined, 19 had concentrations above the MRL. The duplicate samples all had a maximum variation between constituents less than 10 percent (Table 4).

A well that is used by the Forest Service for their facility in Young, Arizona was sampled on two occasions to examine the influence of time on constituent concentrations:

- SRB-16/16D collected in December 2001 and analyzed by the ADHS laboratory, and
- SRB-59 collected in August 2015 and analyzed by Accutest laboratory.

All constituents detected in the original sample were detected in the subsequent sample. Two constituents detected in the second sample, arsenic and selenium, were at concentrations below the MRL for the original sample. Constituent concentration variation was below 11 percent.

Table 3 - Summary Results of Eight Duplicate Samples from ADHS Laboratory

Parameter	Number of Dup. Samples	Difference in Percent			Difference in Concentrations		
		Minimum	Maximum	Median	Minimum	Maximum	Median
Alk., Total	8	0 %	2 %	0 %	0	10	0
SC (µS/cm)	8	0 %	2 %	1 %	0	30	10
Hardness	7	0 %	2 %	0 %	0	5	0
pH (su)	8	0 %	3 %	1 %	0	0.4	0.1
TDS	8	0 %	2 %	1 %	0	20	10
Turbidity (ntu)	6	5 %	12 %	-	0.1	3.6	0.6
Calcium	8	0 %	2 %	0 %	0	2	0
Magnesium	7	0 %	1 %	0 %	0	1	0
Sodium	8	0 %	2 %	0 %	0	10	0
Potassium	8	0 %	5 %	0 %	0	0.1	0
Chloride	8	0 %	1 %	0 %	0	10	0
Sulfate	7	0 %	1 %	0 %	0	1	0
Nitrate (as N)	6	0 %	10 %	0 %	0	0.01	0
T. Phosphorus	3	3 %	21 %	8 %	0.004	0.03	0.008
TKN	1	-	-	6 %	-	-	0.009
Arsenic	1	-	-	5 %	-	-	0.002
Boron	3	0 %	0 %	0 %	0	0	0
Chromium	1	-	-	0 %	-	-	0
Fluoride	7	0 %	1 %	0%	0	0.1	0
Manganese	1	-	-	1 %	-	-	0.01
Selenium	4	0 %	4 %	-	0.001	0.0001	-
Zinc	2	4 %	4 %	-	0.1	0.5	-

All concentration units are mg/L except as noted with certain physical parameters.

Table 4 - Summary Results of Two Duplicate Samples from Accutest Laboratory

Parameter	Number of Dup. Samples	Difference in Percent			Difference in Concentrations		
		Minimum	Maximum	Median	Minimum	Maximum	Median
Physical Parameters and General Mineral Characteristics							
Alk., Total	2	0 %	0 %	-	1	2	-
SC (µS/cm)	2	0 %	0 %	-	0	1	-
Hardness	-	-	-	1 %	-	-	2
pH (su)	2	0 %	0 %	-	0	0.2	-
TDS	2	0 %	1 %	-	2	3	-
Major Ions							
Calcium	1	-	-	0 %	-	-	0.4
Magnesium	1	-	-	-	-	-	0.1
Sodium	2	0 %	1 %	-	0.2	2	-
Potassium	2	0 %	1 %	-	0.006	0.02	-
Chloride	2	0 %	1 %	-	0	0.2	-
Sulfate	1	1 %	3 %	-	0.01	0.04	-
Nutrients							
Nitrate (as N)	1	-	-	3 %	-	-	0.01
Phosphorus	1	-	-	3 %	-	-	0.003
Trace Elements							
Arsenic	1	-	-	0 %	-	-	0
Barium	2	0 %	0 %	-	0	0.0002	-
Boron	1	-	-	2 %	-	-	0.013
Fluoride	2	0 %	0 %	-	0	0	-
Strontium	2	0 %	0 %	-	0	0.0003	-
Zinc	1	-	-	1 %	-	-	0.0005

All concentration units are mg/L except as noted with certain physical parameters.

Split Samples

Splits are identical sets of samples collected from the same source at the same time that are submitted to two different laboratories to check for laboratory differences.[37] The analytical results were evaluated by examining the variability in constituent concentrations in terms of absolute levels and as the percent difference.

Seven inorganic split samples were collected for this study. Five split samples were distributed between the ADHS and Test America (formerly Del Mar) laboratories and two split samples were distributed between the Accutest and Test America laboratories.

Analytical results indicate that of the 41 constituents examined, 19 had concentrations above MRLs for both the ADHS and Test America laboratories. The maximum variation or percent difference between constituents was acceptable at below 20 percent, except for turbidity (39 percent), and fluoride (89 percent) (Table 5).

The fluoride split in question is SRB-21, which had a concentration of 0.57 mg/L that was analyzed by the ADHS laboratory, and SRB-21S, which had a concentration of 9.5 mg/L that was analyzed by Del Mar (Test America) laboratory. No documentation could be found that the sampler contacted the labs to look into the problem. The sample site had sodium-bicarbonate water chemistry and an elevated arsenic concentration, so it's possible the higher fluoride concentration is correct. However, the results from the split sample was deemed nonacceptable not used in further analysis.

Two inorganic split samples were distributed between the Accutest and Test America labs. Analytical results indicate that of the 29 constituents examined, 17 had concentrations above MRLs for both the Accutest and Test America labs. The maximum variation between constituents was acceptable at below 20 percent (Table 6).

Based on the results of the equipment blanks along with the duplicate, split, and time-trend samples collected for this study, only one significant QA/QC problem involving fluoride was found with the groundwater quality data.

Figure 9 - ADEQ's Patti Spindler samples a domestic ranch well (SRB-81) near Pinal Creek located north of Globe. The sample met all water quality standards.

Table 5 - Summary Results of Five Split Samples between ADHS / Test America Laboratories

Parameter	Number of Dup. Samples	Difference in Percent			Difference in Concentrations		
		Minimum	Maximum	Median	Minimum	Maximum	Median
Physical Parameters and General Mineral Characteristics							
Alk., Total	5	0 %	2 %	0 %	0	10	0
SC (µS/cm)	5	0 %	1 %	0 %	0	10	0
Hardness	5	0 %	4 %	2 %	0	25	5
pH (su)	5	1 %	5 %	2 %	0.1	0.78	0.24
TDS	5	0 %	6 %	2 %	0	40	10
Turbidity	2	31 %	39 %	-	1.1	4.7	-
Major Ions							
Calcium	5	1 %	5 %	1 %	1	6	1
Magnesium	5	0 %	5 %	2 %	0	2.0	0.3
Sodium	5	2 %	6 %	3 %	1	10	4
Potassium	4	3 %	5 %	4 %	0.1	0.4	0.1
Chloride	4	1 %	17 %	-	10	13	-
Sulfate	5	0 %	7 %	4 %	0	40	2
Nutrients							
Nitrate (as N)	2	7 %	11 %	-	0.015	0.11	-
TKN	1	-	-	1.02	-	-	86 %
Trace Elements							
Arsenic	1	-	-	3 %	-	-	0.001
Barium	1	-	-	5 %	-	-	0.02
Fluoride	5	0 %	89 %	5 %	0	8.93	0.06
Iron	1	-	-	3 %	-	-	0.05
Manganese	1	-	-	2 %	-	-	0.01

All units are mg/L except as noted [31, 32]

Table 6 - Summary Results of Two Split Samples between Accutest/Test America Laboratories

Constituent	Number of Split Samples	Difference in Percent		Difference in Concentrations	
		Minimum	Maximum	Minimum	Maximum
Physical Parameters and General Mineral Characteristics					
Alk., Total	2	4 %	4 %	4	6.3
SC (µS/cm)	2	0 %	2 %	1	10
Hardness	1	-	2 %	-	6
pH (su)	2	0 %	0 %	0.4	0.9
Turbidity (ntu)	1	-	18 %	-	1.3
TDS	2	14 %	15 %	28	52
Major Ions					
Calcium	2	1 %	4 %	0.6	0.9
Magnesium	1	-	2 %	-	0.5
Sodium	2	4 %	14 %	0.3	1.9
Potassium	1	-	12 %	-	0.25
Chloride	1	-	2 %	-	0.6
Sulfate	1	-	2 %	-	0.6
Nutrients					
Nitrate (as N)	2	1 %	8 %	0.04	0.1
Phosphorus, Ttl	1	-	4 %	-	0.002
Trace Elements					
Aluminum	1	-	4 %	-	0.025
Barium	2	1 %	2 %	0.0005	0.0004
Strontium	2	2 %	4 %	0.005	0.1

All units are mg/L except as noted

Data Validation

The analytical work for this study was subjected to four QA/QC correlations.

Cation/Anion Balances

Water samples should theoretically exhibit electrical neutrality. Therefore, the sum of milliequivalents per liter (meq/L) of cations should equal the sum of meq/L of anions. However, this neutrality rarely occurs due to unavoidable variation inherent in all water quality analyses. Still, if the cation/anion balance is found to be within acceptable limits, it can be assumed there are no gross errors in concentrations reported for major ions.[38]

Overall, cation/anion meq/L balances of Salt River basin samples were significantly correlated (regression analysis, $p \leq 0.01$). Of the 75 samples, all samples were within +/-10 percent and 72 samples were within +/- 5 percent. Of these, 38 samples had high cation/low anion sums, and 37 samples had low cation/high anion sums.

The three samples with large balance discrepancies were collected from sites in the White Mountains that had very low TDS concentrations. Thus, small analytical errors in these samples can result in large percentage errors.

SC-TDS Correlations and Ratio

Specific conductivity, measured both in the field and by contract laboratories, was significantly correlated with total dissolved solids (TDS) concentrations measured by contract laboratories (regression analysis, $r = 0.98$, $p \leq 0.01$).

The TDS concentration in mg/L should be from 0.55 to 0.75 times the SC in µS/cm for groundwater up to several thousand TDS mg/L. The relationship of TDS to SC becomes undefined with very high or low concentrations of dissolved solids.[39] Most of the 77 samples were within this ratio and some that were not could be attributed to elevated TDS concentrations.

Other samples outside the ratio were attributed to elevated concentrations of specific anions. Groundwater high in bicarbonate and chloride will have a multiplication factor near the lower end of this range; groundwater high in sulfate may reach or even exceed the higher factor.[40]

SC Correlation

The SC measured in the field at the time of sampling was significantly correlated with the SC measured by contract laboratories (regression analysis, $r = 0.99$, $p \leq 0.01$).

Figure 10 - ADEQ's Joe Harmon demonstrates that groundwater sampling takes place in many types of weather conditions.

pH Correlations

The pH values measured in the field using an YSI meter at the time of sampling were significantly correlated with laboratory pH values (regression analysis, r = 0.81, p ≥ 0.01) (Figure 11).

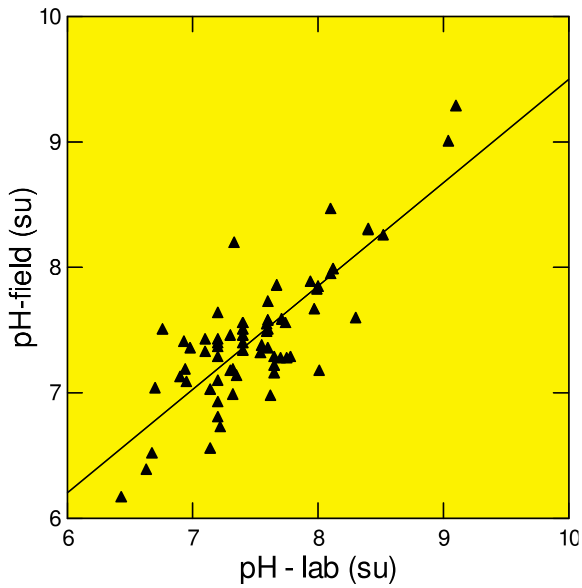


Figure 11 - Graph comparing pH field and lab values described by the equation: y = 0.80x + 1.6. The pH value is related to the environment of the water and is often altered by storage.[41]

Data Validation Conclusions

Based on the results of the four QA/QC checks, the groundwater quality data collected for the study was considered valid.

Statistical Considerations

Data Normality

Data associated with 21 constituents were tested for non-transformed normality using the Kolmogorov-Smirnov one-sample test with the Lilliefors option.[42] Results of this test revealed that five of the 21 constituents examined were normally distributed: temperature, pH-lab, bicarbonate, and deuterium.

Spatial Relationships

The non-parametric Kruskal-Wallis test using untransformed data was applied to investigate the hypothesis that constituent concentrations from sample sites having different sub-basins were the same. The Kruskal-Wallis test uses the differences, but also incorporates information about the magnitude of each difference. The null hypothesis of identical mean values for all data sets within each test was rejected if the probability of obtaining identical means by chance was less than or equal to 0.05.[43]

If the null hypothesis was rejected for the tests conducted on the sub-basin group, the Tukey method of multiple comparisons on the ranks of data was applied. The Tukey test identified significant differences between constituent concentrations when compared to each possibility with each of the tests. Both the Kruskal-Wallis and Tukey tests are not valid for data sets with greater than 50 percent of the constituent concentrations below the MRL.[44]

Constituent Concentrations

In order to assess the strength of association between constituents, their concentrations were compared to each other using the non-parametric Kendall's tau-b test. Kendall's correlation coefficient varies between -1 and +1; with a value of +1 indicating that a variable can be predicted perfectly by a positive linear function of the other. A value of -1 indicates a perfect inverse or negative relationship.[45]

The results of the Kendall's tau-b test were then subjected to a probability test to determine which of the individual pair wise correlations were significant.[34] The Kendall's tau-b test is not valid for data sets with greater than 50 percent of the constituent concentrations below the MRL.[46]

Groundwater Sampling Results

Water Quality Standards

The ADEQ ambient groundwater program characterizes regional groundwater quality. An important determination ADEQ makes concerning the collected samples is how the analytical results compare to various human health based water quality standards. ADEQ used three sets of water quality standards that reflect the best current scientific and technical judgment available to evaluate the suitability of groundwater in the basin for drinking water use:

- Federal Safe Drinking Water Act (SDWA) Primary Maximum Contaminant Levels (MCLs). These enforceable health-based standards establish the maximum concentration of a constituent allowed in water supplied by public systems.[47]

- State of Arizona Aquifer Water Quality Standards. These apply to aquifers that are classified for drinking water protected use. All aquifers within Arizona are currently classified and protected for drinking water use. These enforceable state standards are identical to the federal Primary MCLs except for arsenic which is at 0.05 mg/L compared with the federal Primary MCL of 0.01 mg/L.[48]

- Federal SDWA Secondary MCLs. These non-enforceable aesthetics-based guidelines define the maximum concentration of a constituent that can be present without imparting unpleasant taste, color, odor, or other aesthetic effects on the water.[49]

Health-based drinking water quality standards (such as Primary MCLs) are based on the lifetime consumption (70 years) of two liters of water per day and, as such, are chronic rather than acute standards.[50] Specific constituent concentrations for each groundwater site are in Appendix B.

Overall Results

The 75 sites sampled in the Salt River study had the following water quality results:

- All health-based and aesthetics-based water quality standards were met at 43 sites (57 percent) (Figure 13).
- Health-based water quality standards were exceeded at 13 sites (17 percent).
- Aesthetics-based water quality standards were exceeded at 27 sites (36 percent).

Inorganic Results

Of the 75 sites sampled for the full suite of inorganic constituents (excluding radionuclide sample results) 67 sites (89 percent) met all health-based and aesthetics-based, water quality standards.

Health-based Primary MCL water quality standards were exceeded at 8 of the 75 sites (11 percent) (Figure 12; Table 7). Constituents above Primary MCLs include arsenic (8 sites) and fluoride (1 site). Potential health impacts of these Primary MCL exceedances are provided in Table 7.

Aesthetics-based Secondary MCL water quality guidelines were exceeded at 27 sites (36 percent; Figure 12; Table 8). Constituents above Secondary MCLs include TDS (14 sites), chloride (3 sites), fluoride (2 sites), sulfate (2 sites), aluminum (4 sites), and pH-field (4 sites), iron (6 sites), manganese (5 sites), and zinc (1 site).

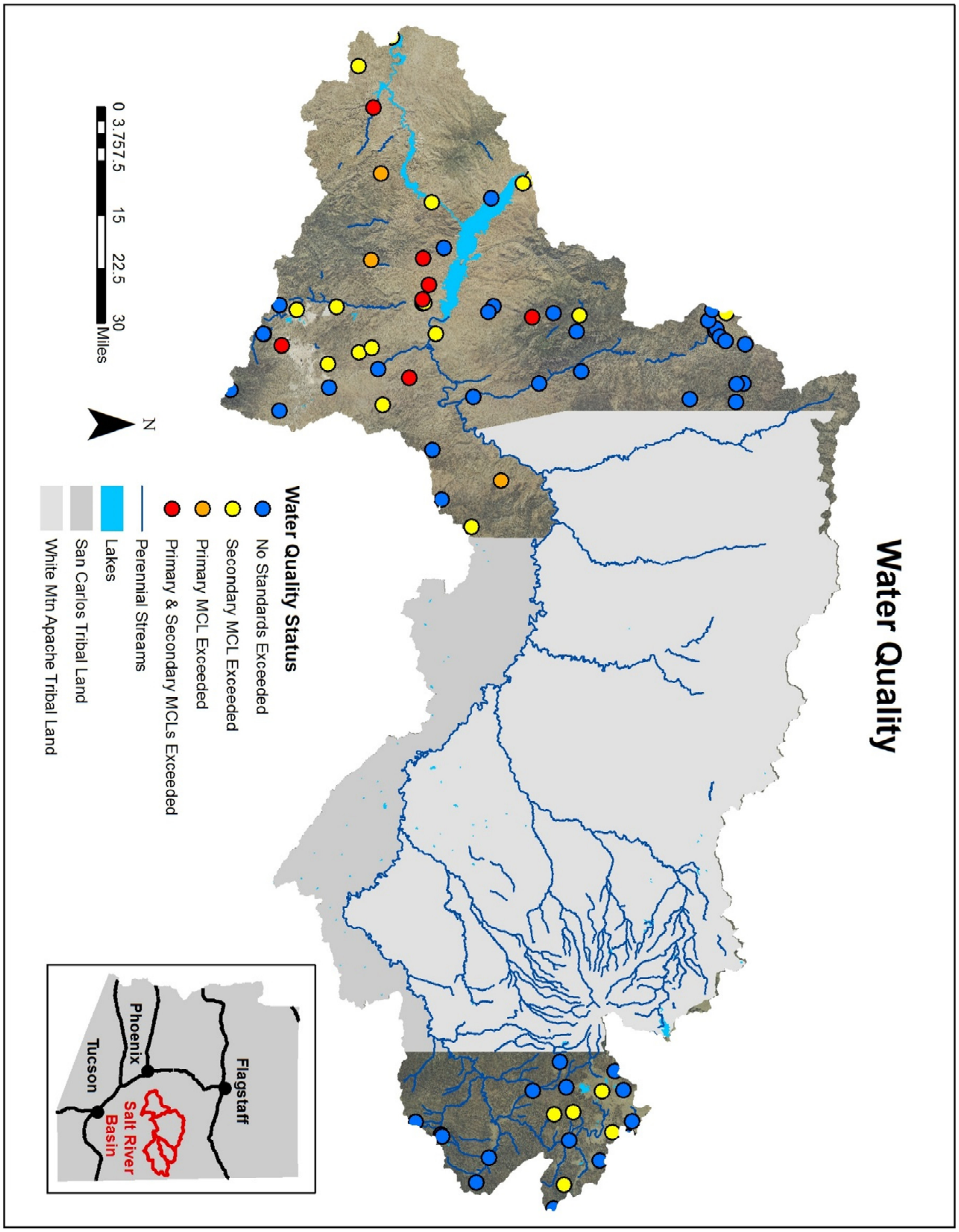


Figure 12 - Water Quality Map

Table 7 - Sample Sites Exceeding Health-based Water Quality Standards or Primary MCLs

Constituent	Primary MCL	Number of Sites Exceeding Primary MCL	Maximum Concentration	Potential Health Effects of MCL Exceedances *
Nutrients				
Nitrite (NO_2-N)	1.0	0	-	-
Nitrate (NO_3-N)	10.0	0	-	-
Trace Elements				
Antimony (Sb)	0.006	0	-	-
Arsenic (As)	0.01	**8**	0.16	dermal and nervous system toxicity
Arsenic (As)	0.05	0	-	-
Barium (Ba)	2.0	0	-	-
Beryllium (Be)	0.004	0	-	-
Cadmium (Cd)	0.005	0	-	-
Chromium (Cr)	0.1	0	-	-
Copper (Cu)	1.3	0	-	-
Fluoride (F)	4.0	**1**	4.0	skeletal damage
Lead (Pb)	0.015	0	-	-
Mercury (Hg)	0.002	0	-	-
Nickel (Ni)	0.1	0	-	-
Selenium (Se)	0.05	0	-	-
Thallium (Tl)**	0.002	0	-	-
Radiochemistry Constituents				
Gross Alpha	15	**4**	37	cancer
Ra-226+Ra-228	5	0	-	-
Radon **	300	**10**	2,967	cancer
Radon **	4,000	0	-	-
Uranium	30	**3**	38	cancer and kidney toxicity

All units are mg/L except gross alpha, radium-226+228 and radon (pCi/L), and uranium (ug/L).
* Health-based drinking water quality standards are based on a lifetime consumption of two liters of water per day over a 70-year life span.[51]
** Proposed EPA Safe Drinking Water Act standards for radon in drinking water. [52]

Table 8 - Sample Sites Exceeding Aesthetics-based Water Quality Guidelines/Secondary MCLs

Constituents	Secondary MCL	Number of Sites Exceeding Secondary MCLs	Maximum Concentration	Aesthetic Effects of MCL Exceedances
Physical Parameters				
pH - field	< 6.5	**2**	6.17	bitter metallic taste; corrosion
pH - field	> 8.5	**2**	9.29	slippery feel; soda taste; deposits
General Mineral Characteristics				
TDS	500	**14**	1,700	hardness; deposits; colored water; staining; salty taste
Major Ions				
Chloride (Cl)	250	**3**	877	salty taste
Sulfate (SO_4)	250	**2**	790	salty taste
Trace Elements				
Aluminum (Al)	0.05 to 0.2	**4**	0.369	colored water
Fluoride (F)	2.0	**3**	4.0	tooth discoloration
Iron (Fe)	0.3	**6**	12.0	rusty color; sediment; metallic taste; reddish or orange staining
Manganese (Mn)	0.05	**5**	0.415	black to brown color; black staining; bitter metallic taste
Silver (Ag)	0.1	0	-	-
Zinc (Zn)	5.0	**1**	**5.75**	metallic taste

All units mg/L except pH is in standard units (su).

Potential health impacts of these Secondary MCL exceedances are given in Table 8.

Radionuclide Results

Of the 49 sites sampled for radionuclides, health-based Primary MCL water quality standards were exceeded at five sites (10 percent). Constituents exceeding standards include gross alpha (four sites) and uranium (three sites).

Radon Results

Fourteen sites were sampled for radon, and had the following results.

The proposed 4,000 picocuries per liter (pCi/L) standard that would apply if Arizona establishes an enhanced multimedia program to address the health risks from radon in indoor air was not exceeded at any sites.

The proposed 300 pCi/L standard that would apply if Arizona doesn't develop a multimedia program was exceeded at 10 sites (71 percent).[53]

Analytical Results

Analytical inorganic and radiochemistry results of the Salt River basin sample sites are summarized (Table 9 and Table 10) using the following indices: MRLs, number of sample sites over the MRL, upper and lower 95 percent confidence intervals ($CI_{95\%}$), median, and mean. Confidence intervals are a statistical tool which indicates that 95 percent of a constituent's population lies within the stated confidence interval.[34] Specific constituent information for each sampled groundwater site is found in the Appendices.

Well driller Leroy Tucker, ADEQ's Elizabeth Boettcher, and ADOT's Terry Cline pose as a domestic well is being purged for sampling in the Roosevelt Estates area located south of Lake Roosevelt. The sample (SRB-74) from the well met all water quality standards.

Figure 13 – Purging a domestic well in the Salt River Lakes sub-basin.

Table 9 - Summary Statistics for Groundwater Quality Data

Constituent	Minimum Reporting Limit (MRL)*	# of Samples / Samples Over MRL	Median	Lower 95% Confidence Interval	Mean	Upper 95% Confidence Interval
Physical Parameters						
Temperature (ºC)	0.1	75 / 68	18.8	16.4	17.9	19.5
pH-field (su)	0.01	75 / 68	7.40	7.32	7.45	7.58
pH-lab (su)	1.68 / -	75 / 75	7.55	7.42	7.54	7.65
Turbidity (ntu)	0.2 / 0.5	73 / 53	0.25	0.75	2.93	5.12
General Mineral Characteristics						
T. Alkalinity	6.0 / 5.0	75 / 75	193	158	182	206
SC-field (µS/cm)	N/A	75 / 68	460	433	571	708
SC-lab (µS/cm)	2.0 / 1.0	75 / 75	450	440	572	702
Hardness-lab	13 / 33	75 / 71	177	162	199	236
TDS	20 / 10	75 / 75	270	273	347	420
Major Ions						
Calcium	2 / 5	75 / 73	45	39	48	57
Magnesium	2 / 5	75 / 63	13.6	15.0	18.6	22.2
Sodium	2 / 10	75 / 75	16	23	44	65
Potassium	2 / 0.5	75 / 69	1.7	1.6	2.0	2.4
Bicarbonate	Calculation	75 / 75	232	191	220	249
Carbonate	Calculation	75 / 3	> 50 percent of data below MRL			
Chloride	20 / 50	75 / 74	10	13	44	76
Sulfate	20 / 5	75 / 72	14	25	49	73
Nutrients						
Nitrate (as N)	0.2 / 0.1	75 / 56	0.29	0.41	0.66	0.91
Nitrite (as N)	0.2 / 0.1	75 / 1	> 50% of data below MRL			
TKN	1.0 / 0.2	77 / 18	> 50% of data below MRL			
Ammonia	0.05 / 1.0	75 / 2	> 50% of data below MRL			
T. Phosphorus	0.1 / 0.02	77 / 41	> 60% of data below MRL			

* = Standard Test America / Accutest MRL but these sometimes can vary   All units mg/L except where noted.

Table 10 - Summary Statistics for Groundwater Quality Data

Constituent	Minimum Reporting Limit (MRL)*	# of Samples / Samples Over MRL	Median	Lower 95% Confidence Interval	Mean	Upper 95% Confidence Interval
Trace Elements						
Aluminum	0.2	73 / 5	> 50% of data below MRL			
Antimony	0.003 / 0.006	75 / 0	> 50% of data below MRL			
Arsenic	0.003 / 0.01	73 / 22	> 50% of data below MRL			
Barium	0.001 / 0.2	75 / 36	> 50% of data below MRL			
Beryllium	0.001 / 0.005	75 / 0	> 50% of data below MRL			
Boron	0.2 / 0.1	75 / 8	> 50% of data below MRL			
Cadmium	0.001 / 0.002	75 / 1	> 50% of data below MRL			
Chromium	0.002 / 0.01	75 / 0	> 50% of data below MRL			
Copper	0.003 / 0.01	75 / 5	> 50% of data below MRL			
Fluoride	0.4 / 0.1	75 / 57	0.21	0.23	0.42	0.61
Iron	0.1 / 0.2	75 / 12	> 50% of data below MRL			
Lead	0.001 / 0.01	75 / 3	> 50% of data below MRL			
Manganese	0.01 / 0.015	75 / 8	> 50% of data below MRL			
Mercury	0.0002	75 / 0	> 50% of data below MRL			
Nickel	0.01 / 0.005	75 / 1	> 50% of data below MRL			
Selenium	0.002 / 0.01	75 / 4	> 50% of data below MRL			
Silver	0.001 / 0.005	75 / 0	> 50% of data below MRL			
Strontium	0.1 / 0.01	35 / 35	0.16	0.13	0.24	0.32
Thallium	0.001 / 0.01	75 / 0	> 50% of data below MRL			
Zinc	0.05 / 0.02	75 / 19	> 50% of data below MRL			
Radiochemical						
Gross α (pCi/L)	Varies	52 / 33	1.5	2.4	4.5	6.7
Uranium (pCi/L)	Varies	18 / 13	3.9	2.5	7.9	13.3
Isotopes						
O-18 (0/00)	Varies	35 / 35	-10.50	-10.52	-10.21	-9.90
D (0/00)	Varies	35 / 35	-73.80	-74.27	-72.59	-70.92
$\delta^{15}N$ (0/00)	Varies	35 / 35	4.75	4.83	5.93	7.03

Groundwater Composition

General Summary

Water chemistry in the Salt River basin, in decreasing frequency, was calcium-bicarbonate (36 sites), mixed-bicarbonate (24 sites), sodium-bicarbonate (five sites), sodium-chloride, sodium-mixed, and magnesium-bicarbonate (two sites apiece), and one site apiece for calcium-sulfate, calcium-mixed, calcium-chloride, and mixed-mixed (Figure 14 – middle diagram). These varying water chemistry types are spatially shown in Figure 15.

Calcium-bicarbonate chemistry is predominant in the Black River and Salt River Canyon sub-basins while the Salt River Lakes sub-basin encompasses a wide spectrum of water chemistry.

The dominant cation was calcium at 38 sites (left diagram). The dominant anion was bicarbonate at 66 sites (right diagram).

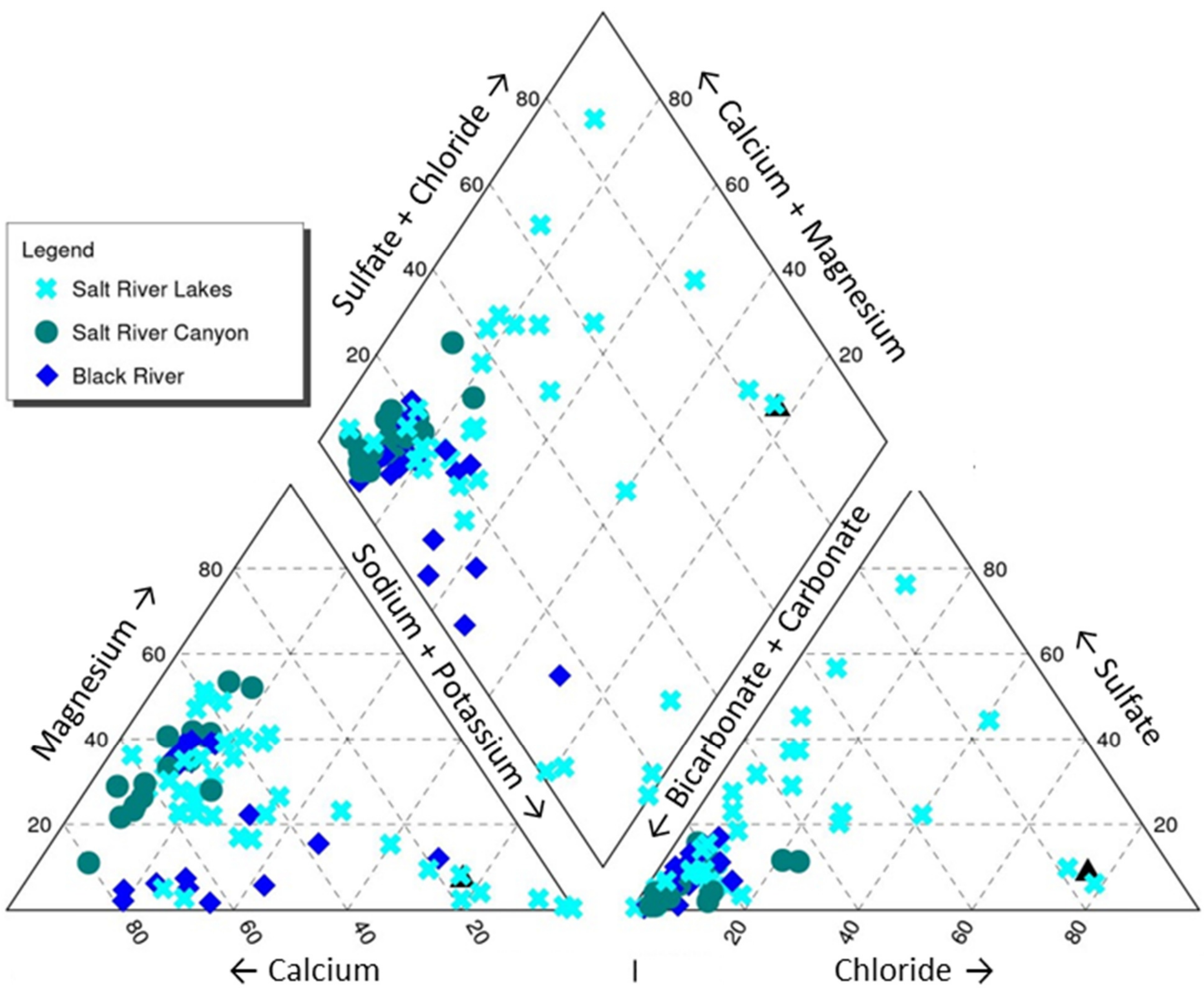


Figure 14 – The Piper diagram shows that most samples are of calcium/mixed-bicarbonate chemistry.

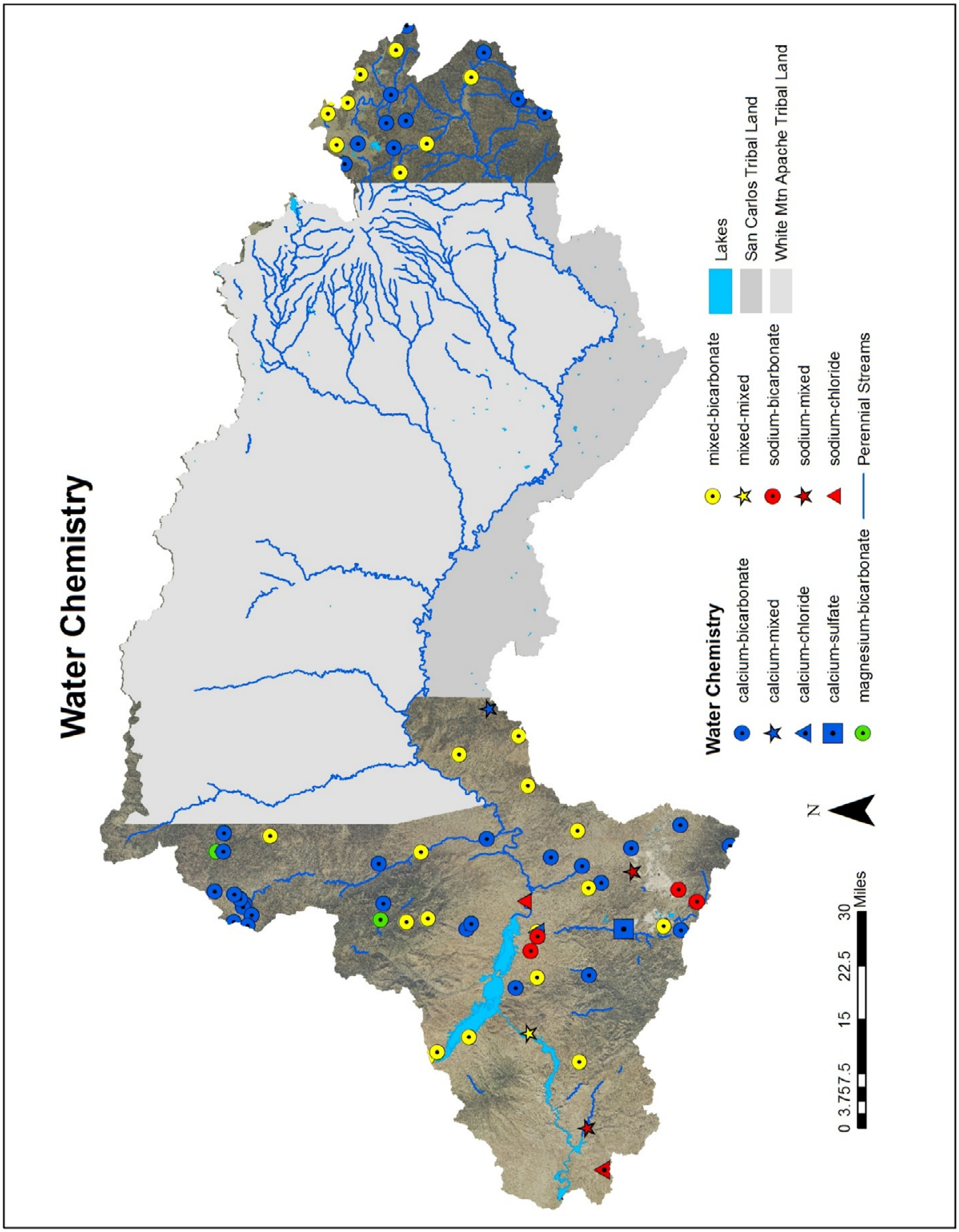


Figure 15 - Water Chemistry Map.

At nine sites, levels of pH-field were *slightly acidic* (below 7 su). At 52 sites, levels of pH-field were *slightly alkaline* (7 - 8 su), five sites were above 8 su, and two sites were above 9 su. [12] The pH prove was no working at eight sites.

TDS concentrations were considered *fresh* (below 999 mg/L) at 72 sites and *slightly saline* (1,000 to 3,000 mg/L) at three sites (Figure 16).[12]

Hardness concentrations were *soft* (below 75 mg/L) at 23 sites, *moderately hard* (75 – 150 mg/L) at seven sites, *hard* (150 – 300 mg/L) at 28 sites, *very hard* (301 - 600 mg/L) at 16 sites, and *extremely hard* (above 601 mg/L) at one site (Figure 17).[10]

Nitrate (as nitrogen) concentrations at most sites may have been influenced by human activities according to a prominent nationwide USGS study.[22] Nitrate concentrations were divided into natural background (33 sites at < 0.2 mg/L), may or may not indicate human influence (39 sites at 0.2 – 3.0 mg/L), may result from human activities (three sites at 3.0 – 10 mg/L), and probably result from human activities (zero sites > 10 mg/L).[17]

Most trace elements such as aluminum, antimony, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, thallium, and selenium were rarely – if ever - detected. Only arsenic, barium, fluoride, strontium, and zinc were detected at more than 20 percent of the sites.

The groundwater at each sample site was assessed as to its suitability for irrigation use based on salinity and sodium hazards. Excessive levels of sodium are known to cause physical deterioration of the soil and vegetation. Irrigation water may be classified using SC and the Sodium Adsorption Ratio (SAR) in conjunction with one another.[33]

Groundwater sites in the Salt River basin display a narrow range of irrigation water classifications. Samples predominantly had a "low" sodium hazard and a "low to high" salinity hazard (Table 11).

Table 11 - Sodium and Salinity Hazards for Sample Sites

Hazard	Total Sites	Low	Medium	High	Very High
Sodium Hazard					
Sodium Adsorption Ratio (SAR)		0 - 10	10- 18	18 - 26	> 26
Sample Sites	75	70	3	1	1
Salinity Hazard					
Specific Conductivity (µS/cm)		0–250	250 – 750	750-2250	>2250
Sample Sites	77	21	39	13	2

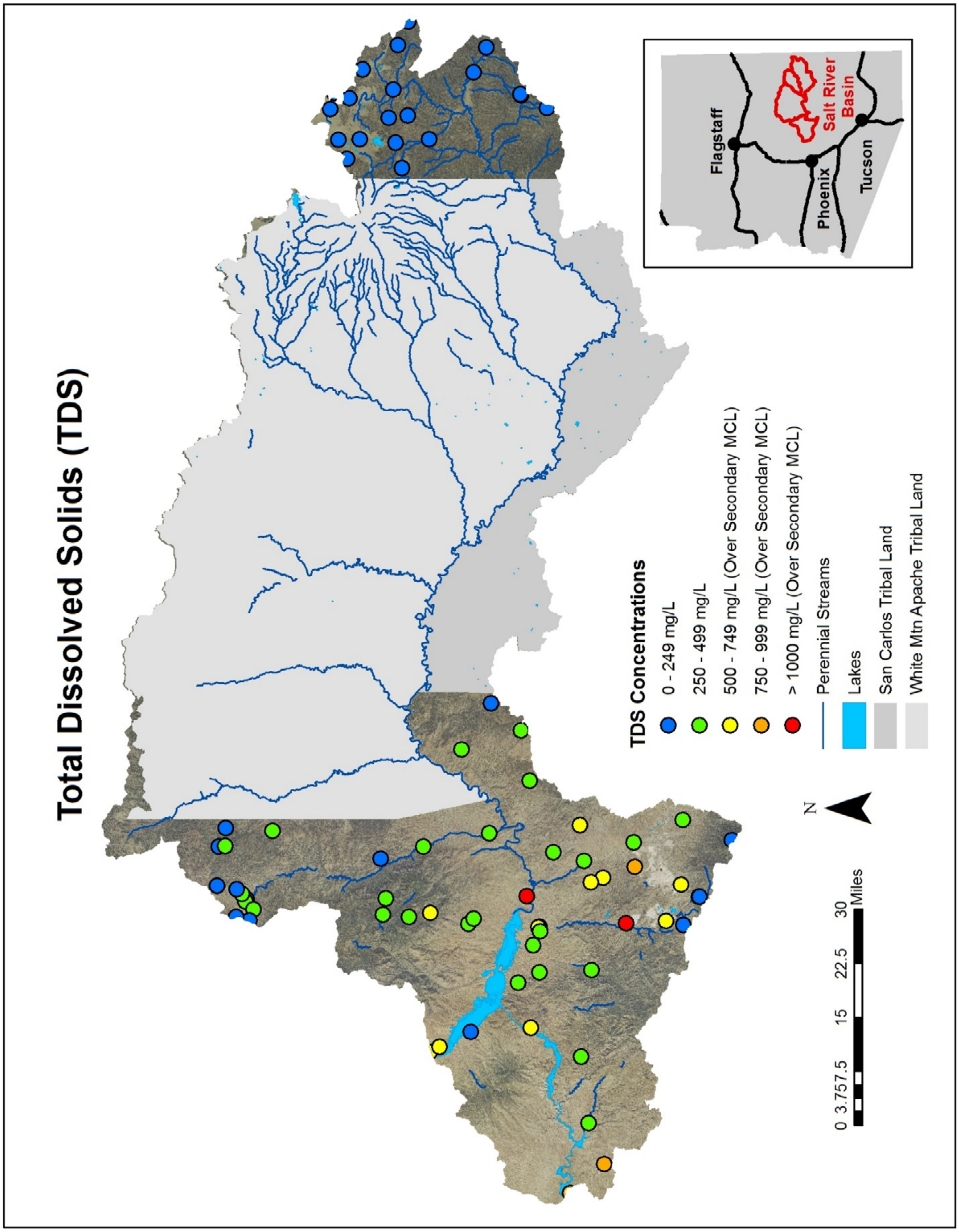


Figure 16 - TDS Map.

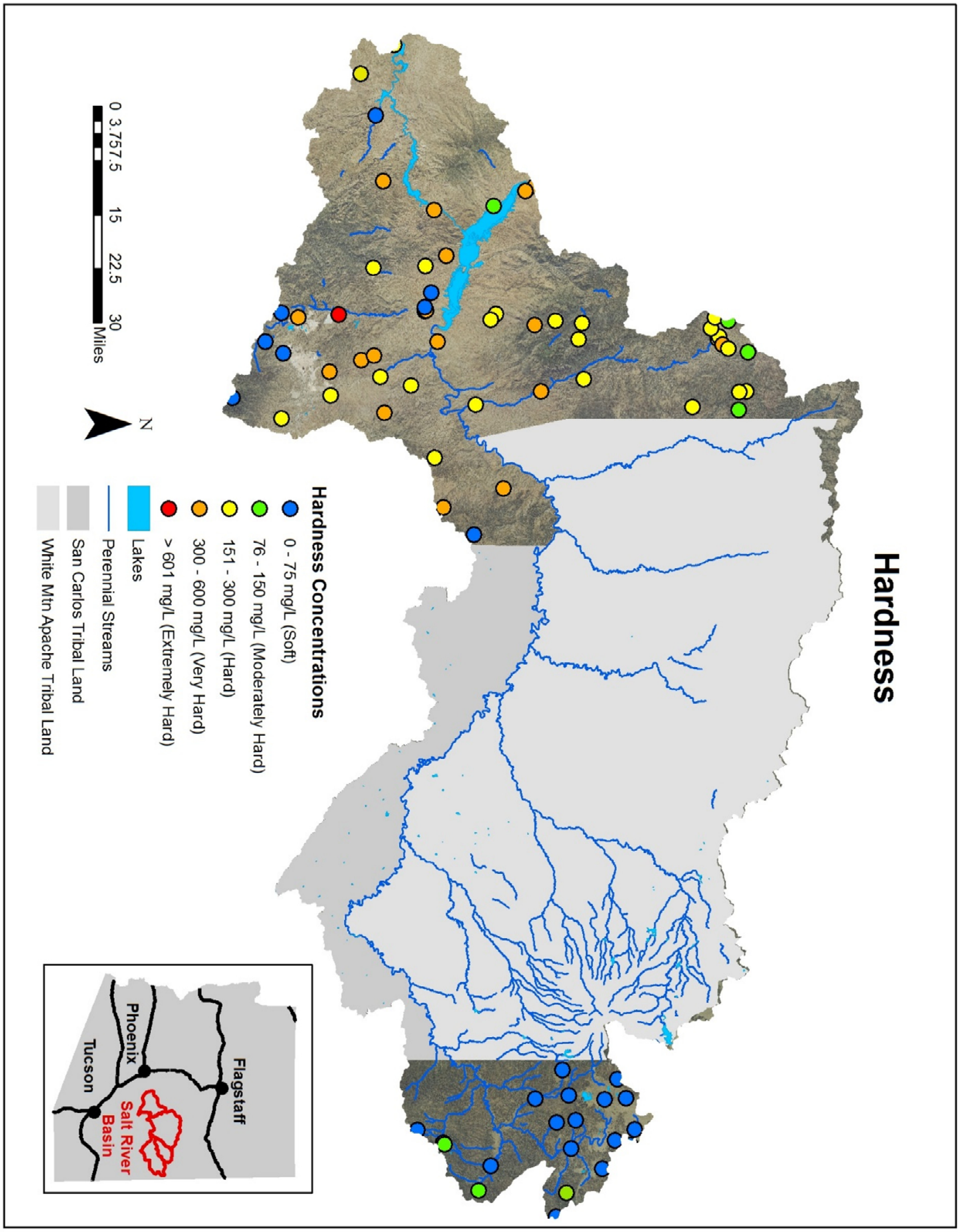


Figure 17 - Hardness Map.

Constituent Covariation

The correlations between different chemical parameters were analyzed to determine the relationship between the constituents that were sampled. The strength of association between the chemical constituents allows for the identification of broad water quality patterns within a basin.

The results of each combination of constituents were examined for statistically-significant positive or negative correlations. A ***positive correlation*** occurs when, as the level of a constituent increases or decreases, the concentration of another constituent also correspondingly increases or decreases. A ***negative correlation*** occurs when, as the concentration of a constituent increases, the concentration of another constituent decreases, and vice-versa. A positive correlation indicates a direct relationship between constituent concentrations; a negative correlation indicates an inverse relationship.[34]

Several significant correlations occurred among the 75 sample sites (Table 12, Kendall's tau-b test, $p \leq 0.05$). Three groups of correlations were identified:

- Many constituents were positively correlated with one another: temperature, TDS, hardness (Figure 18), calcium, magnesium, sodium, potassium, bicarbonate, chloride (Figure 19), sulfate, and fluoride.
- pH-field had a positive correlation with sodium and fluoride.
- Nitrate was not correlated with any constituents.

TDS concentrations are best predicted among major ions by sodium concentrations (Figure 12) (standard coefficient = 0.60), among cations by sodium concentrations (standard coefficient = 0.65) and among anions, by chloride concentrations (Figure 13) (standard coefficient = 0.69, multiple regression analysis, $p \leq 0.01$).

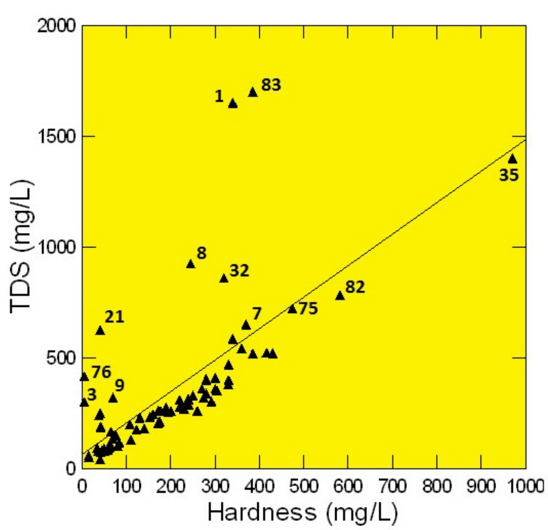


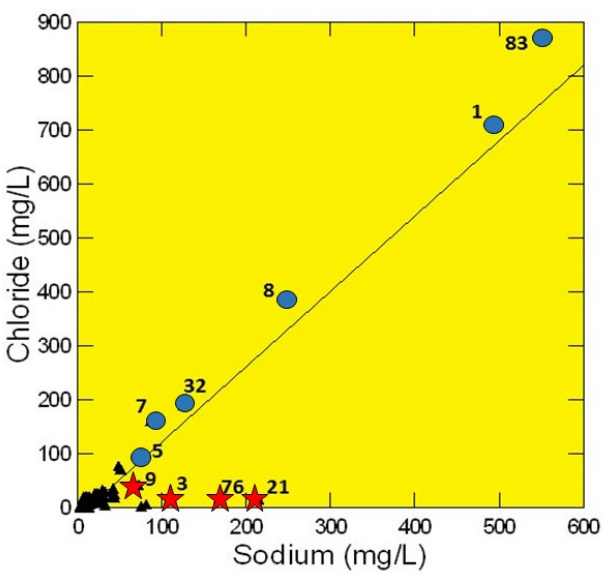
Figure 18 - Relationship between TDS and hardness.

The relationship between TDS and hardness highlights the sites with unusual water chemistry in the basin. The samples above the regression line, such as SRB-1, 8, 21, 32, and 83 have sodium-dominated water chemistry. The samples to the far right edge of the graph have water chemistries mostly unique to the basin, such as calcium-chloride (SRB-75) and calcium-sulfate (SRB-35).

Table 12. Correlation among Groundwater Quality Constituent Concentrations

Constituent	Temp	pHf	TDS	Hard	Ca	Mg	Na	K	Bic	Cl	SO_4	NO_3	F	O	D
Physical Parameters															
Temperature		**	**	**	**	**	**	**	**	**	**		**	**	**
pH-field							**						**		
General Mineral Characteristics															
TDS				**	**	**	**	**	**	**	**		**	**	**
Hardness					**	**	**	**	**	**	**		**		
Major Ions															
Calcium						**	**	**	**	**	**		**		
Magnesium							**	**	**	**	**		**	**	
Sodium								**	**	**	**		**	**	
Potassium										**	**		**	**	
Bicarbonate										**	**		**	**	
Chloride											**		**	**	**
Sulfate													**	**	**
Nutrients															
Nitrate															
Trace Elements															
Fluoride														**	**
Isotopes															
Oxygen-18															**
Deuterium															

Blank cell = not a significant relationship between constituent concentrations
* = Significant positive relationship at $p \leq 0.05$
** = Significant positive relationship at $p \leq 0.01$
+ = Significant negative relationship at $p \leq 0.05$
++ = Significant negative relationship at $p \leq 0.01$



The chloride-sodium relationship highlights how water chemistry impacts arsenic concentrations. Sample sites with high concentrations of the two constituents that are on or above the regression line (SRB-1, 5, 7, 8, 32, and 83, which are shown with a blue circle) have no arsenic Primary MCL exceedances. Samples below the regression line that are only high in sodium concentrations (SRB-3, 9, 21, and 76 which are designated with a red star) without the accompanying elevated chloride all have arsenic Primary MCL exceedances.

Figure 19 – Sodium-Chloride Relationship with Arsenic Exceedances.

Oxygen and Hydrogen Isotopes

Groundwater characterizations using oxygen and hydrogen isotope data may be made with respect to the climate and/or elevation where the water originated, residence within the aquifer, and whether or not the water was exposed to extensive evaporation prior to collection. This is accomplished by comparing oxygen-18 isotopes ($\delta^{18}O$) and deuterium (δD), an isotope of hydrogen, data to the Global Meteoric Water Line (GMWL).

The GMWL is described by the linear equation:

$$\delta D = 8\ \delta^{18}O + 10$$

where δD is deuterium in parts per thousand (per mil, $^{0}/_{00}$), 8 is the slope of the line, $\delta^{18}O$ is oxygen-18 $^{0}/_{00}$, and 10 is the y-intercept. The GMWL is the universal reference standard based on worldwide precipitation without the effects of evaporation.[54]

Isotopic data from a region may be plotted to create a Local Meteoric Water Line (LMWL) which is affected by varying climatic and geographic factors. When the LMWL is compared to the GMWL, inferences may be made about the origin of the local water.[55]

Meteoric waters exposed to evaporation are enriched and characteristically plot increasingly below and to the right of the GMWL. Evaporation tends to preferentially contain a higher percentage of lighter isotopes in the vapor phase and causes the water that remains behind to be isotopically heavier. In contrast, meteoric waters that experience little evaporation are depleted and tend to plot increasing to the left of the GMWL and are isotopically lighter. [56]

Groundwater from arid environments is typically subject to evaporation, which enriches δD and $\delta^{18}O$, resulting in a lower slope value (usually between 3 and 6) as compared to the slope of 8 associated with the GMWL.

Salt River Basin Isotope Results

Oxygen and hydrogen isotope samples were collected from 35 sites sampled in the second phase of the Salt River basin study.

The Local Meteoric Water Line (LMWL) formed by the samples has a slope of 4.9 (Figure 20), which is common for an arid environment and is described by the linear equation:

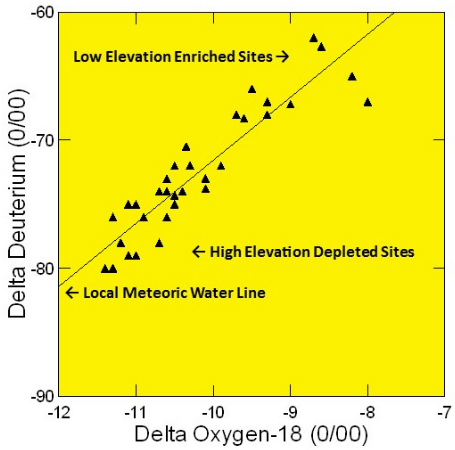
$$\boldsymbol{\delta D = 4.9\ ^{18}O - 28.8.}$$

Oxygen and deuterium isotope values at most sites in the Salt River basin appear to reflect recharge occurring at various elevations within the basin. This suggests that much of the groundwater was recharged from recent precipitation.[57]

Isotope values did, however, exhibit variability that allowed them to be divided into two groups: lower elevation (10 sites) and higher elevation (25 sites).

Although there are some significant differences between constituent concentrations, comparing sampling sites by sub-basin proved much more significant. This is possibly because the isotope samples were collected at only 47 percent of sites. (Figure 14).

The LMWL of 4.9 for the Salt River basin is similar to other basins in Arizona (Figure 21): [58]



The 35 isotope samples are graphed according to their oxygen-18 and deuterium values to form the basin's Local Meteoric Water Line (LMWL), which reflects the climate and/or elevation where the water originated. The isotope values generally conform to elevations of the sample sites in the Salt River basin.

Figure 20 - The Salt River Basin's Local Meteoric Water Line.

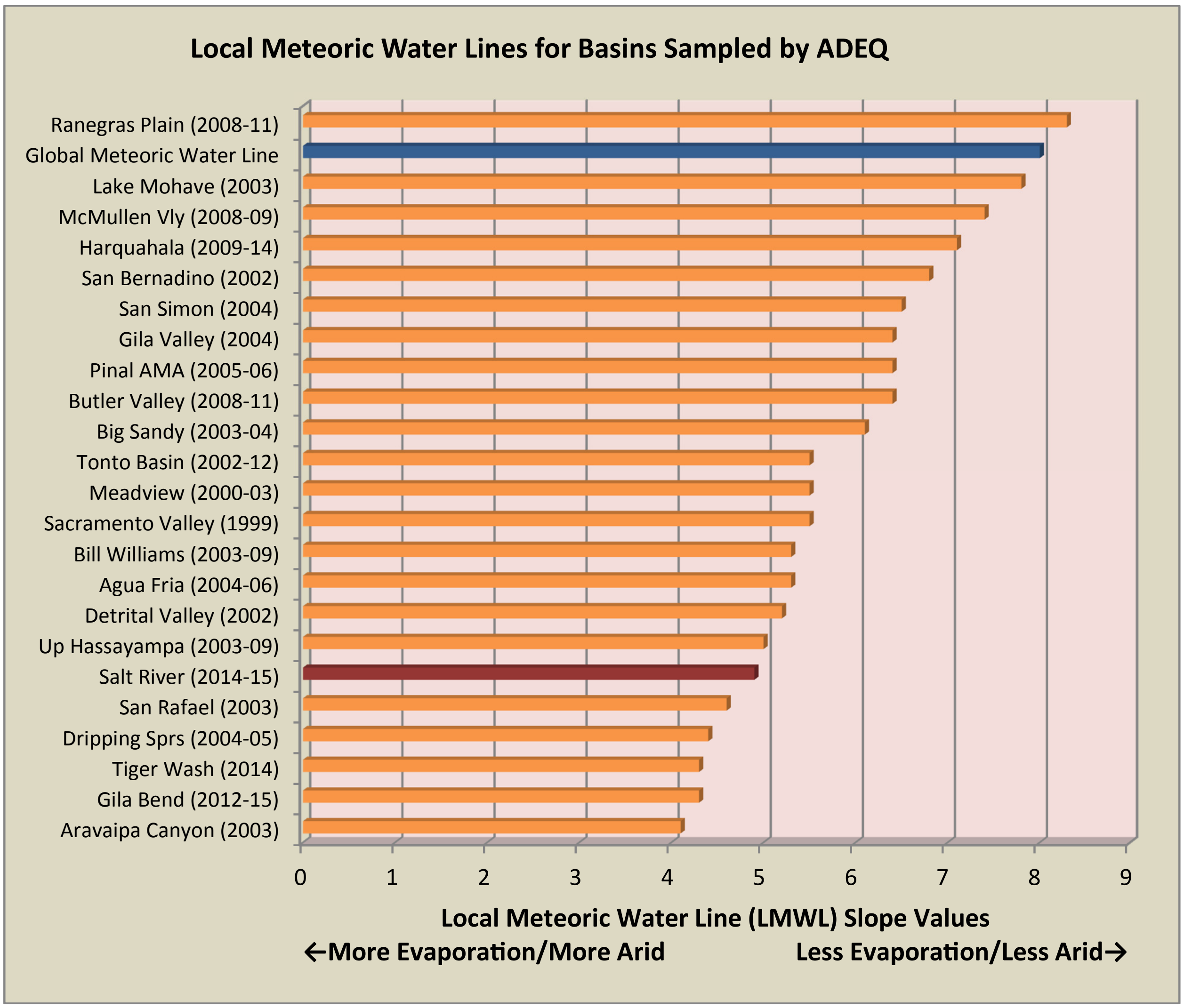


Figure 21 - Local Meteoric Water Lines (LMWL) from ADEQ Ambient Groundwater Studies in Arizona.

Nitrogen Isotopes

Sources of nitrate in groundwater may be distinguished by measuring two stable isotopes of nitrogen, nitrogen-14 and nitrogen-15, often represented by $\delta^{15}N$. Although the percentage of the two isotopes is nearly constant in the atmosphere, certain chemical and physical processes preferentially utilize one isotope, causing a relative enrichment of the other isotope in the remaining reactants.

Groundwater samples for $\delta^{15}N$ analysis were collected at 35 sites, where they were sampled in the second phase of the study. The $\delta^{15}N$ values ranged from +0.7 to +12.8 0/00 while the associated nitrate values ranged from non-detect to 5.95 mg/L (Figure 22).

Because of these isotopic fractionation processes, nitrate from different nitrogen sources has been shown to have different N isotope ratios. The $\delta^{15}N$ values have been cited as ranging from +2 to +9 per mil for natural soil organic matter sources, -3 to +3 for inorganic fertilizer sources, +10 to +20 per mil for animal waste.[59]

Nitrogen-15 results in the basin fall into the following categories:

- Organic soil matter (+2 to +9) – 24 sites,
- Fertilizer (-3 to +3) – 3 sites,
- Animal waste (+10 to +20) – 6 sites,
- Undetermined (+9 to +10) – 2 sites
- Undetermined (> +20) – 0 sites

Based on these results, it appears that the nitrogen source is predominantly organic soil matter.

The sites with the five highest nitrate (as N) concentrations, however, are all associated with $\delta^{15}N$ values that would indicate the nitrogen source is animal waste. At all five sites, there were either livestock on the property (SRB-57/58, 61, 62, and 69) and/or the onsite septic system likely receives a high volume of use such as at the Forest Service's Hannigan Meadow Campground (SRB-55).

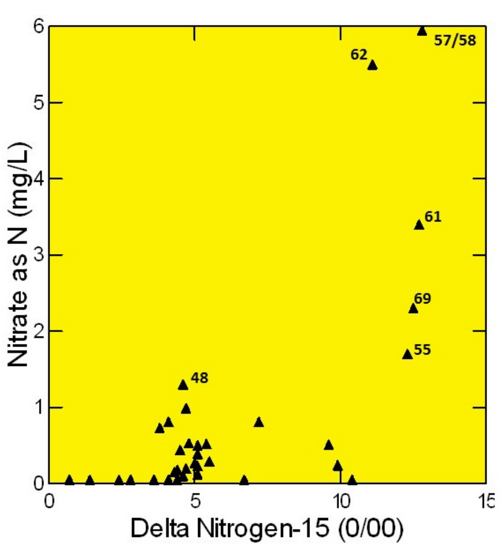


Figure 22 - Nitrate-Nitrogen-15 Relationship.

Based on a subset of the 35 sites sampled in the Salt River basin, elevated nitrate (as nitrogen) concentrations of more than 2.0 mg/L are likely the result of impacts from animal waste, either from horses on the property or from septic systems that receive substantial use such as a rest room for a forest service campground.

Groundwater Quality Variation

The spatial variation of groundwater quality was examined by comparing constituent concentrations among three Salt River sub-basins:

- **Black River** (**BR**) – 19 sites were sampled in the most upgradient sub-basin;
- **Salt River Canyon** (**SR Canyon**) – 17 sites were sampled in the sub-basin west of the Fort Apache Tribal lands; and
- **Salt River Lakes** (**SR Lakes**) – 39 sites were sampled in the most downgradient sub-basin.
- There were no sites sampled in the **White River sub-basin**, which is almost entirely on tribal land.

Significant concentration differences were found with 15 constituents: oxygen-18, deuterium, temperature, pH-lab, SC-field, SC-lab, TDS (Figure 23), hardness, calcium (Figure 24), magnesium, sodium, potassium, bicarbonate, sulfate, and fluoride (Kruskal-Wallis and Tukey tests, $p \leq 0.05$). No significant differences were found with six constituents: pH-field, turbidity, chloride, nitrate (Figure 25 and Figure 26), nitrogen-15, and strontium.

Complete statistical results are in Table 13 and 95 percent confidence intervals for significantly different sub-basin groups are in Table 14.

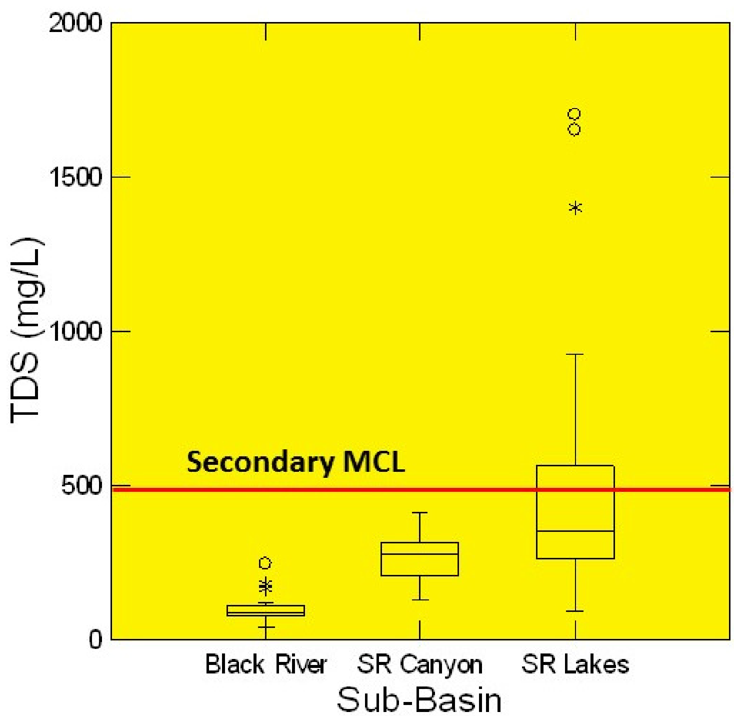
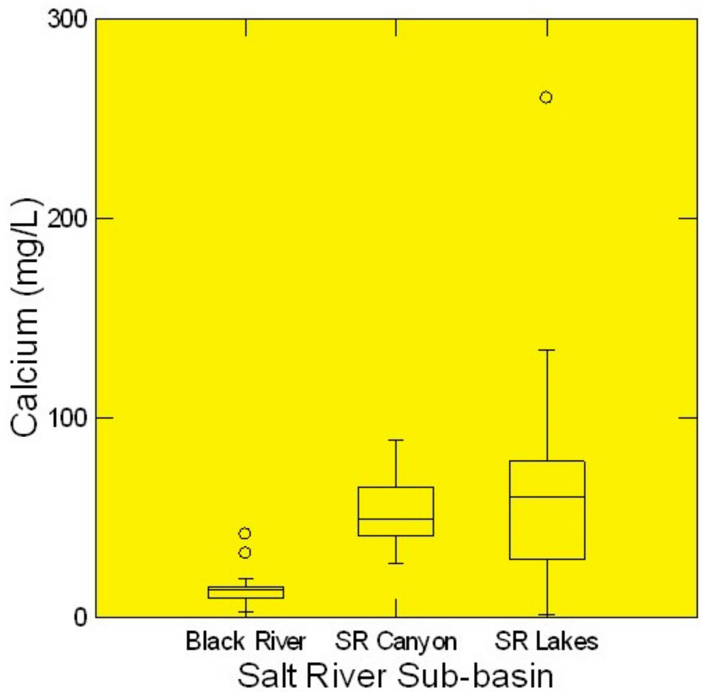


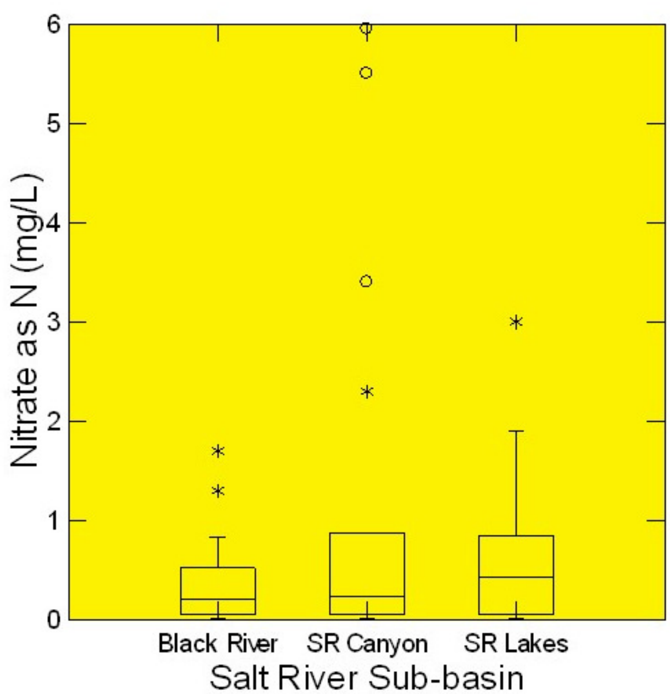
Figure 23 - TDS variation among Salt River sub-basins.

TDS concentrations in the Salt River Lakes sub-basin are significantly higher than in both the Salt River Canyon and Black River sub-basins (Kruskal-Wallis and Tukey tests, $p \leq 0.01$). The TDS boxplot, however, shows that salinity is not a major problem in the basin as only a few sample sites in the Salt River Lakes sub-basin exceeded the Secondary MCL of 500 mg/L.



Calcium concentrations in the Salt River Lakes and Salt River Canyon sub-basins are significantly higher than in the Black River sub-basin (Kruskal-Wallis and Tukey tests, $p \leq 0.01$). Constituent concentrations in the Salt River Canyon sub-basin usually are significantly less than the Salt River Lakes sub-basin, except for five constituents: temperature, hardness, calcium, magnesium, and bicarbonate.

Figure 24 - Calcium variation among Salt River sub-basins.



Nitrate concentrations do not significantly differ between the three sub-basins in the Salt River basin. As opposed to most other constituents, whose concentrations are controlled by natural sources on a regional scale, elevated nitrate concentrations are largely well-specific and land uses in the immediate vicinity of the well are a major influence.

Figure 25 - Nitrate variation among Salt River sub-basins.

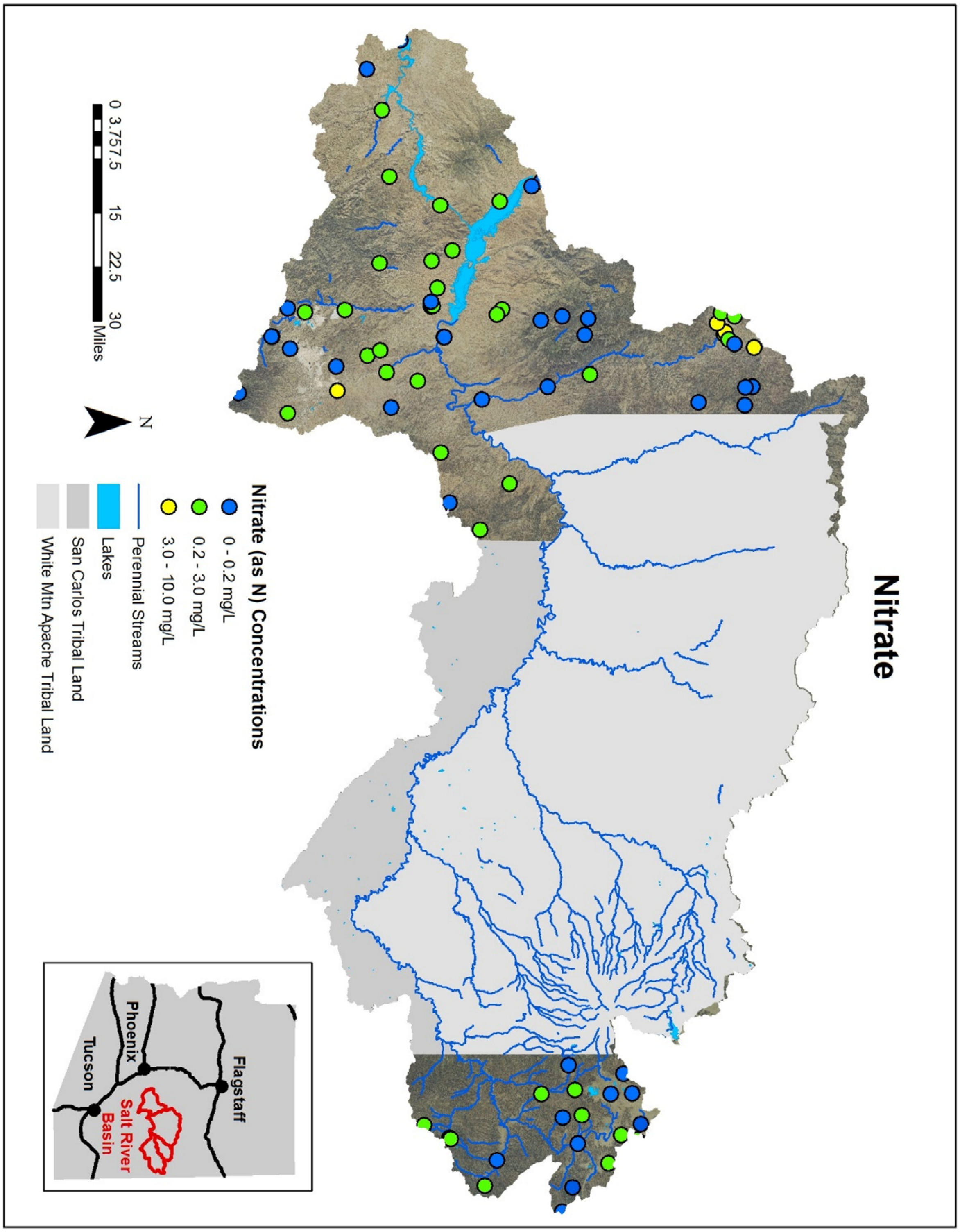


Figure 26 – Nitrate Map.

Table 13 - Variation in Constituent Concentrations among Three Sub-basins

Constituent	Sites Sampled	Significance	Significant Differences Between Three Sub-basins
Oxygen	35	**	Salt River Lakes > Black River**
Deuterium	35	**	Salt River Lakes > Salt River Canyon & Black River*
Temperature - field	68	**	Salt River Lakes & Salt River Canyon > Black River**
pH – field	68	ns	-
pH – lab	75	**	Salt River Lakes > Black River*
SC - field	68	**	Salt River Lakes > Salt River Canyon * & Black River**
SC - lab	75	**	Salt River Lakes > Salt River Canyon * & Black River**
TDS	75	**	Salt River Lakes > Salt River Canyon ** & Black River**
Turbidity	73	ns	-
Hardness	75	**	Salt River Lakes & Salt River Canyon > Black River**
Calcium	75	**	Salt River Lakes & Salt River Canyon > Black River**
Magnesium	75	**	Salt River Lakes & Salt River Canyon > Black River**
Sodium	75	**	Salt River Lakes > Salt River Canyon * & Black River**
Potassium	75	**	Salt River Lakes > Salt River Canyon & Black River**
Bicarbonate	75	**	Salt River Lakes & Salt River Canyon > Black River**
Chloride	75	**	-
Sulfate	75	**	Salt River Lakes > Salt River Canyon * & Black River**
Nitrate (as N)	75	ns	-
$\delta^{15}N$	35	ns	-
Fluoride	75	**	Salt River Lakes > Black River*
Strontium	35	ns	-

Table 14 – 95 Percent Confidence Intervals for Constituents among Three Sub-basins

Constituent	Significance	Black River	Salt River Canyon	Salt River Lakes
Oxygen	**	-11.01 to -10.35	-	-11.30 to -8.20
Deuterium	**	-76.72 to -71.78	-77.4 to-71.5	- 65.2 to -63.2
Temperature - field	**	8.8 to 11.8	16.9 to 21.7	19.0 to 22.5
pH – field	ns	-	-	-
pH – lab	**	7.05 to 7.54	-	7.50 to 7.84
SC - field	**	110 to 180	376 to 521	591 to 1058
SC - lab	**	104 to 185	389 to 541	607 to 1044
TDS	**	78 to 125	232 to 311	378 to 619
Turbidity	ns	-	-	-
Hardness	**	43 to 78	183 to 257	198 to 317
Calcium	**	11 to 19	44 to 62	48 to 78
Magnesium	**	3.7 to 7.2	15.5 to 28.1	18 to 29
Sodium	**	3.1 to 9.5	9.6 to 16.4	38 to 115
Potassium	**	0.6 to 1.1	1.0 to 2.1	2.2 to 3.4
Bicarbonate	**	55 to 104	211 to 307	236 to 307
Chloride	**	-	-	-
Sulfate	**	3.3 to 6.2	6.1 to 21.0	-
Nitrate (as N)	ns	-	-	-
$\delta^{15}N$	-	-	-	-
Fluoride	**	0.6 to 0.12	-	0.3 to 1.0
Strontium	ns	-	-	-

Discussion

The Salt River basin, through which the Salt River Project's series of four dams on the Salt River provides much of the Phoenix metropolitan area's water supply, contains some of the best groundwater in Arizona, as judged by water quality standards and salinity levels (Figure 27).

The large basin, which stretches almost from the New Mexican border east to the Phoenix AMA, contains four sub-basins. Water quality varies among the sub-basins, as constituent concentrations typically increase as the water moves from up-gradient to downgradient areas.

Sub-Basins - The most pristine groundwater is found in the uppermost Black River sub-basin, in which all the sample sites met health-based water quality exceedances.

Samples collected in the Black River sub-basin had significantly lower temperature, pH, SC, TDS, hardness, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and fluoride concentrations than was found in the most downgradient sub-basin, the Salt River Lakes.

Fort Apache and San Carlos tribal lands encompass significant portions of both the Black River and Salt River Canyon sub-basins and all of the White River sub-basin. No sites were sampled in the White River sub-basin. Based on the data from other sub-basins, however, it's likely that the water quality in the White River sub-basin has few water quality standard exceedances and is low in salinity.

The Salt River Canyon sub-basin is the next downgradient sub-basin and, depending on the constituent, has concentrations similar to the up-gradient Black River sub-basin or the downgradient Salt River Canyon sub-basin.

Figure 27 - ADEQ's Patti Spindler collects a sample from Little Walnut Spring (SRB-80). The spring met all water quality standards, like 57 percent of the sample sites in the Salt River basin.

The downgradient Salt River Lakes sub-basin has significantly higher concentrations of most constituents, the greatest water chemistry variability, and the most Primary and Secondary MCL exceedances.

Water Quality Standards - Groundwater in the Salt River basin is generally suitable for drinking water uses based on the sampling results from this study. These results differ from an earlier water quality assessment in the basin, which was focused on the Globe-Miami area. Most of this area is encompassed by the ADEQ Pinal Creek WQARF site.[60]

In ADWR's water atlas, using historical data, the agency identified 70 wells in the basin with constituent concentrations exceeding health-based Primary MCLs. All but one exceedance was from the Globe-Miami area, which has a long and extensive history of copper mining. Cadmium was the most common exceedance; other constituents exceeding standards included fluoride, beryllium, copper, lead, chromium, nitrate, arsenic, and radionuclides.[61]

Acidic, low pH water with elevated concentrations of metals including aluminum, barium, copper, manganese, and iron was identified north of Globe-Miami area. This plume also contains high sulfate concentrations that travel faster than the elevated metal concentrations. The contamination was created by water draining from areas disturbed by mining activities. The plume is approximately nine miles long in the alluvial aquifer along Pinal Creek and Miami Wash, and is slowly moving downgradient towards the Salt River.[62] The Lower Pinal Creek treatment plant has been in place since 1999 to treat the acidic, polluted water.

Arsenic, fluoride, gross alpha, and uranium were the only constituents found above Primary MCLs in this ADEQ study. These are common contaminants throughout the state.[63]

Constituents that exceeded Primary MCLs in the ADEQ study will be discussed below.

Arsenic - Arsenic exceeded health-based, water quality standards in samples collected from eight sites, with concentrations as high as 0.16 mg/L, more than ten times the 0.01 mg/L standard (Figure 28).

The highest arsenic concentrations in the study are associated with a sodium water chemistry, but Primary MCL exceedances can occasionally occur in calcium- water chemistry too.

Arsenic concentrations are affected by reactions with hydroxyl ions and are influenced by factors such as an oxidizing environment, lithology, and aquifer residence time. [64]

Fluoride - Fluoride exceeded the 4.0 mg/L health-based, water quality standards in samples collected from two wells, with concentrations as high as 5.05 mg/L. These wells also had arsenic exceedances, as elevated concentrations of these two constituents frequently occur together (Figure 29).

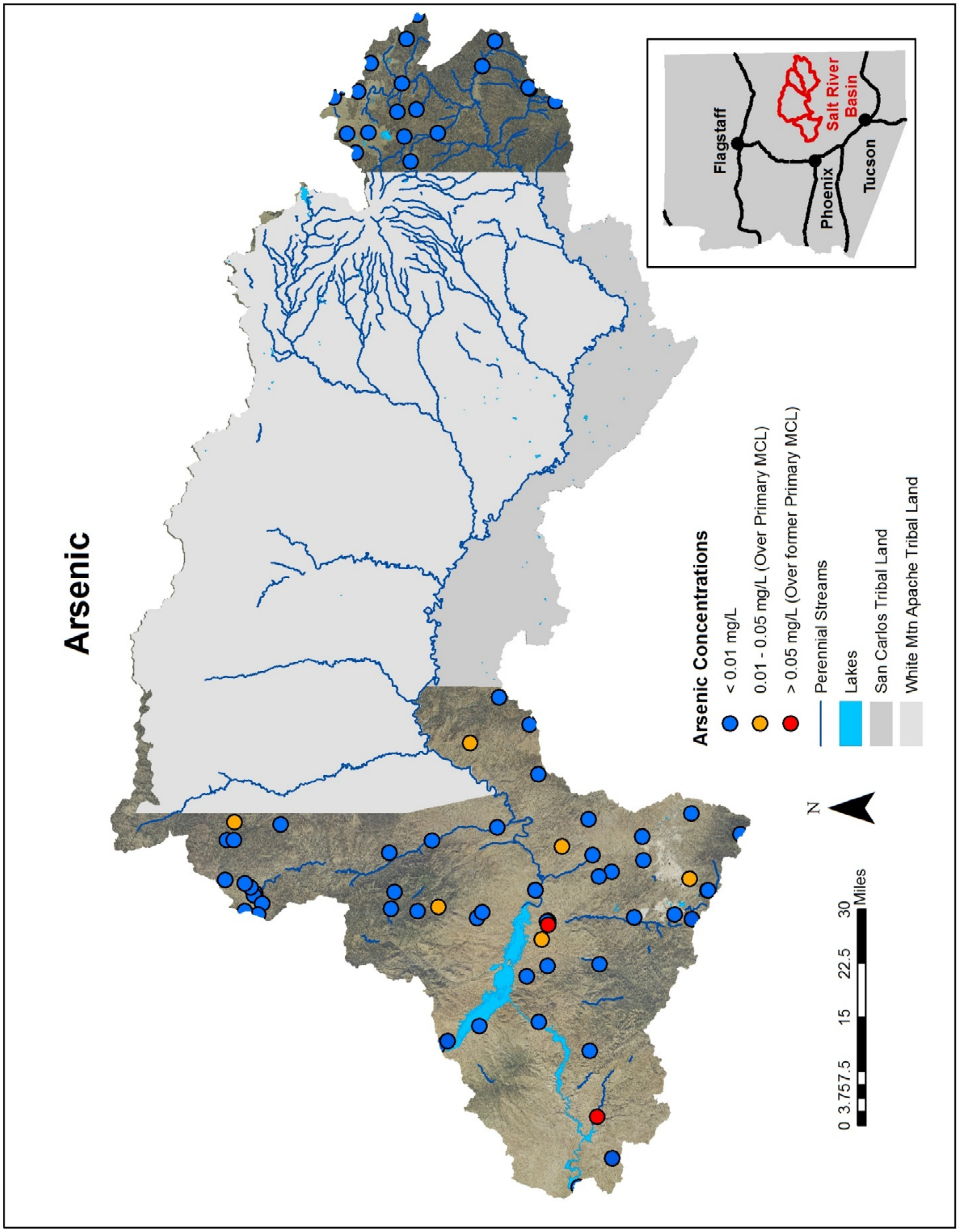


Figure 28 - Arsenic Map.

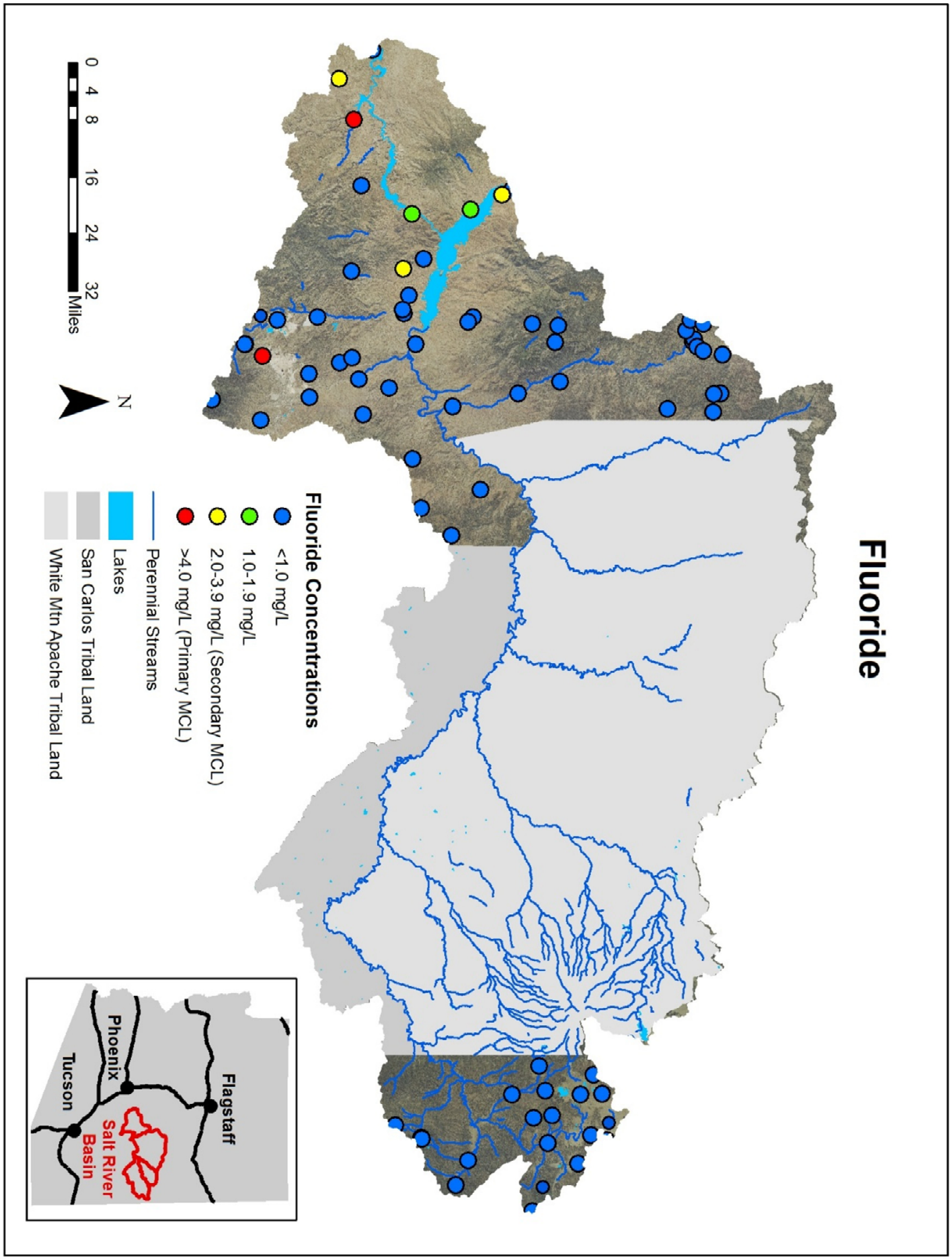


Figure 29 - Fluoride Map.

Fluoride concentrations in groundwater are often controlled by calcium through precipitation or dissolution of the mineral fluorite. In a chemically closed hydrologic system, calcium is removed from solution by precipitation of calcium carbonate and the formation of smectite clays. Concentrations exceeding 5 mg/L of dissolved fluoride may occur in groundwater depleted in calcium if a source of fluoride ions is available for dissolution.[65]

Sites only partially depleted in calcium may be controlled by processes other than fluorite dissolution. Hydroxyl ion exchange or sorption-desorption reactions have also been cited as providing controls on lower (< 5 mg/L) levels of fluoride. As pH values increase downgradient, greater levels of hydroxyl ions may affect an exchange of hydroxyl for fluoride ions thereby increasing fluoride in solution. [66]

Fluoride concentrations are significantly higher in the Salt River Lakes sub-basin than in the Black River sub-basin; with the levels in the Salt River Canyon sub-basin not significantly different from the other two sub-basins (Map 11).

Gross Alpha and Uranium - Of the 52 radionuclide samples collected, gross alpha exceeded Primary MCLs at four sites, uranium at three sites. Two sites had both gross alpha and uranium exceedances.

Of the five sites with radionuclide water quality exceedances, four were located in granitic geology, which is associated with elevated radionuclide concentrations in groundwater.[67] The only other exceedance was SRB-41, located south of Globe in sedimentary geology.

TDS – All of the 75 sites sampled, 14 exceeded the Secondary MCL of 500 mg/L. Most TDS exceedances were minor, with only three sites exceeding 1,000 mg/L, more than twice the Secondary MCL.

Two of these sites (SRB-1 and SRB-83) were wells that served the Rock House Store along U.S. Highway 288 just north of the Salt River. The wells are located near marshes created when water backs up from Roosevelt Lake when the reservoir is near capacity. The high salt content of the groundwater is likely related to evaporate deposits from the lake.

The other site with an elevated TDS concentration is Peak Well #50, which is owned by BHP Copper, in the Globe-Miami area. The well is located northwest of the mines near Pinto Creek and its high TDS concentrations are the result of a sulfate plume moving downgradient. The well has a sulfate concentration of 790 mg/L, and is one of only three sulfate exceedances in the basin.

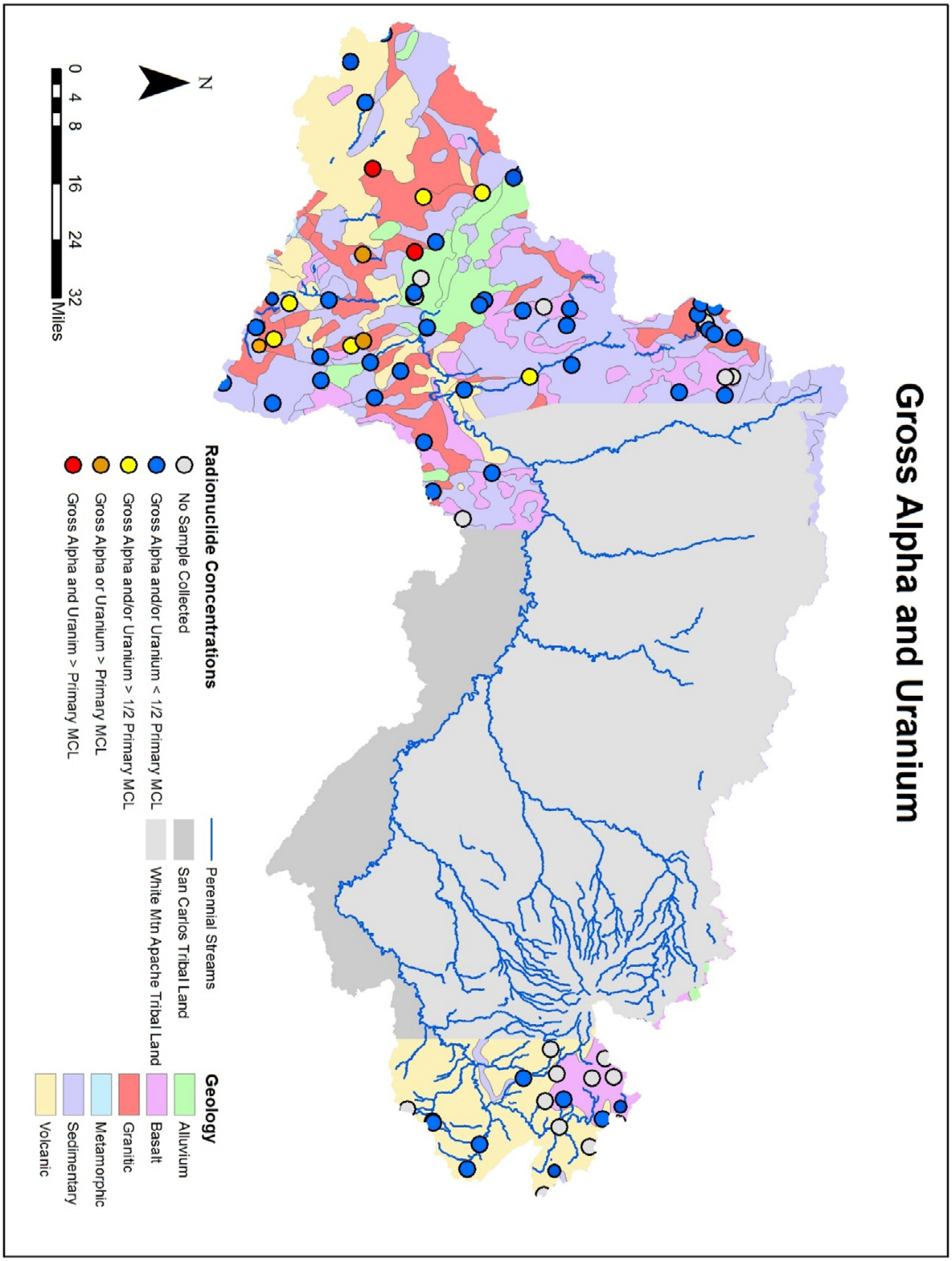


Figure 30 – Radionuclide and Geology Map.

Appendices

Appendix A. Data for Sample Sites, Salt River Basin, 2001 -2015

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Sub-basin
1st Field Trip, October 17, 2001 – Boettcher & Lucci									
SRB-1	A (3-14)5add submersible	33.631295 110.937328	804050	51319	Rock Hous Well	Inorganic, Radon O,H & N Isotopes	40’	20’	Salt River Lakes
SRB-2	A(4-13)36ccd spring	33.728480 110.993270	804050	59400	A-Cross Spring	Inorganic, Radon O,H & N Isotopes	-	-	Salt River Lakes
SRB-3/3D duplicate	A(3-13)9bc submersible	33.620569 111.036847	804043	51230	Grapevine Well	Inorganic, Radon, VOC & Isotopes	-	-	Salt River Lakes
SRB-4/4S split	A(4-11)2bbb submersible	33.724788 -111.210707	801567	51229	Cholla CampWell	Inorganic, Radiochem O,H & N Isotopes	300’	114’	Salt River Lakes
2nd Field Trip, October 19, 2001 – Harmon & Lucci									
SRB-5/5D duplicate	A(5-11)8abc submersible	33.793922 -111.251383	803618	59401	Indian Point Well	Inorganic, Radiochem Radon, VOC, Isotopes	-	60’	Salt River Lakes
SRB-6	A(4-12)34adc submersible	33.645601 -111.111334	513721	51226	Tonto Mont Well	Inorganic, Radon O,H & N Isotopes	134’	-	Salt River Lakes
SRB-7	A(3-11)2cc submersible	33.624790 -111.202748	601284	58973	Burnt CorralWell	Inorganic, Radon O,H & N Isotopes	71’	15’	Salt River Lakes
3rd Field Trip, October 23, 2001 – Harmon & Lucci									
SRB-8/8D duplicate	A(3-8)33dbc submersible	33.558723 -111.534917	617681	10760	Stewart Well	Inorganic Radionuclides	393’	110’	Salt River Lakes
SRB-9	A(2-9)11ddb submersible	33.527418 -111.393530	600802	59399	Tortilla Flat Well	Inorganic Radionuclides	-	-	Salt River Lakes
4th Field Trip, November 5, 2001 – Boettcher & Lucci (10 and 11 outside basin)									
SRB-12	A(5-28)29cdb spring	33.794392 -109.414951	-	59404	Colonel Spring	Inorganic, VOCs Radionuclide	-	-	Black River
SRB-13	A(4-29)34ddd submersible	33.640701 -109.326672	557878	58897	Hannigan Mdw Well	Inorganic, VOCs Radionuclide	100’	56’	Black River
SRB-14/14S split	A(5-30)3bcc submersible	33.858933 -109.176116	528297	59403	Noble Well	Inorganic, VOCs Radionuclide	200’	55’	Black River
5th Field Trip, December 4-6, 2001 – Harmon & Lucci									
SRB-15/15D duplicate	A(8-15)10bbc submersible	34.055927 -110.806128	612180	59453	Rogers Well	Inorganic Radionuclides	-	60’	Salt River Cyn
SRB-16/16S/59 split/dup	A(9-14)30aad submersible	34.098641 -110.943347	600863	59454	North Well	Inorganic Radionuclides	135’	22’	Salt River Cyn
SRB-17	A(6-13)12cda submersible	33.872194 -110.974956	86019	59455	Reynolds Creek Well	Inorganic Radionuclides	50’	13’	Salt River Lakes
SRB-18	A(5-13)35cab spring	33.720065 -110.982500	-	59457	Sanborn Spring	Inorganic, VOCs Radionuclide	-	-	Salt River Lakes
SRB-19	A(9-15)10ccb submersible	34.133189 -110.800494	647664	59456	Fay Well	Inorganic, VOCs Radionuclide	100’	30’	Salt River Cyn
6th Field Trip, December 4-6, 2001 – Harmon & Lucci									
SRB-19a	A(11-14)35dba spring	34.2935061 -110.814934	-	59477	Cyn Ck Fish Hatch	Inorganic Radionuclide	-	-	Salt River Cyn
6th Field Trip, February 19-21, 2002 – Boettcher & Lucci									
SRB-20/20D duplicate	D(1-13)14ccc submersible	33.337159 -111.018130	561832	59505	Gresham Well	Inorganic, VOCs Radionuclide	380’	100’	Salt River Lakes
SRB-21/21S split	D(1-14)2bcc submersible	33.372864 -110.914457	560511	59506	Schulze Well	Inorganic, VOCs Radionuclide	540’	200’	Salt River Lakes
SRB-22	A(2-15)7abc submersible	33.535084 -110.866857	574127	59507	Hick’s Well	Inorganic Radionuclides	370’	-	Salt River Lakes

Appendix A. Data for Sample Sites, Salt River Basin, 2001-2015

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Sub-basin
SRB-23	D(1-15)2cda submersible	33.369774 -110.783941	571259	59508	Hale's Well	Inorganic Radionuclides	300'	100'	Salt River Lakes
SRB-24	A(3-15)20db windmill	33.586904 -110.849273	600956	59509	-	Inorganic, VOCs Radionuclide	-	-	Salt River Lakes
SRB-25	A(2-14)23ac windmill	33.503204 -110.900455	601075	59510	-	Inorganic, VOCs Radionuclide	-	-	Salt River Lakes
7th Field Trip, March 21, 2002 – Lucci									
SRB-26/26D duplicate	A(2-11)6cdd submersible	33.540076 -111.260321	-	59556	Apache Rnch Well	Inorganic, VOCs Radionuclide	84'	12'	Salt River Lakes
8th Field Trip, April 24-26, 2002 – Boettcher & Lucci									
SRB-27	A(2-12)13bbb spring	33.523415 -111.086192	-	59691	Narran's Spring	Inorganic, VOCs Radionuclide	-'	-	Salt River Lakes
SRB-28/28D duplicate	A(3-12)14aba spring	33.610501 -111.090468	-	59692	Black Brush Well	Inorganic Radionuclides	-	-	Salt River Lakes
SRB-29	A(5-15)5cab spring	33.804254 -110.838151	-	59693	Ellison Ranch Spr.	Inorganic, VOCs Radionuclide	-	-	Salt River Cyn
SRB-30	A(4-15)15aab submersible	33.694374 -110.811674	584126	59694	Section 1 Well #2	Inorganic Radionuclides	100'	-	Salt River Cyn
SRB-31	A(1-15)4dcd submersible	33.452250 -110.829928	544636	59695	Kelly Well	Inorganic, VOCs Radionuclide	220'	-	Salt River Lakes
SRB-32/32S split	A(1-14)12aab submersible	33.450476 -110.877947	519762	59696	BHP Well	Inorganic Radionuclides	445'	174'	Salt River Lakes
SRB-33	A(1-13)25cad submersible	33.398008 -110.987034	500797	59697	Peak Well #37	Inorganic, VOCs Radionuclide	775'	-	Salt River Lakes
SRB-34	A(5-16) spring	33.740716 -110.642354	-	59698	Eagle Bluff Spring	Inorganic Radionuclides	-	-	Salt River Cyn
SRB-35	A(1-13)1bba submersible	33.465163 -110.992744	528180	59699	Peak Well #50	Inorganic Radionuclides	-	0'	Salt River Lakes
9th Field Trip, May 21-22, 2002 – Boettcher & Lucci (38 outside basin)									
SRB-36	A(4-30)6caa spring	33.720216 -109.280813	-	59781	Bardman Spring	Inorganic Radionuclides	-	-	Black River
SRB-37/37D duplicate	A(4-30)15baa submersible	33.699191 -109.230705	511264	59928	Watkins Well	Inorganic Radionuclides	555'	520'	Black River
10th Field Trip, May 28, 2002 – Lucci & Boettcher									
SRB-39	A(6-14)17bac spring	33.866877 -110.941945	615084	59752	Cienega Spring	Inorganic, VOCs Radionuclide	-	-	Salt River Lakes
SRB-40	A(4-17)31ddb spring	33.640969 -110.604565	615084	59753	Bassett-Norris Spr	Inorganic Radionuclides	-	-	Salt River Cyn
11th Field Trip, July 5, 2007 – Towne & Olsen (Travel Blank)									
SRB-41	D(1-14)16 submersible	33.342690 -110.936874	215743	68799	Hale Well	Inorganic, Radiochem Radon, O,H isotope	-	-	Salt River Lakes
SRB-42a	D(1-14)16dba submersible	33.341917 -110.938298	551436	68798	McSpaden Well	Inorganic, Radiochem Radon, O,H, N isotope	321'	8'	Salt River Lakes
12th Field Trip, October 7-9, 2014 – Towne & Boettcher									
SRB-42b	A(6-27)11cad spring	33.93132 -109.45503	-	79521	Trap Spring #2	Inorganic O,H & N Isotopes	-	-	Black River
SRB-43	A(6-28)05bdc spring	33.945482 -109.416372	-	79522	Spence Spring	Inorganic O,H & N Isotopes	-	-	Black River
SRB-44	A(6-29)07cba spring	33.927179 -109.332254	-	79523	O.D. Spring	Inorganic, Radiochem Radon, O,H,N isotope	-	-	Black River
SRB-45	A(6-29)22bbd spring	33.90573 -109.27515	-	79524	Up. North Spring	Inorganic O,H & N Isotopes	-	-	Black River

Appendix A. Data for Sample Sites, Salt River Basin, 2001-2015

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Sub-basin
SRB-46	A(7-29)31dcd spring	33.95278 -109.32272	-	79525	Jessie Spring	Inorganic O,H & N Isotopes	-	-	Black River
SRB-47	A(6-28)17cdc spring	33.90991 -109.41471	-	79526	SU Knoll Spring	Inorganic, Radon O, H & N isotopes	-	-	Black River
SRB-48	A(5-28)07aab spring	33.85005 -109.422545	-	79527	Conklin Spring	Inorganic O,H & N Isotopes	-	-	Black River
SRB-49	A(5-28)15add spring	33.83003 -109.36784	-	79528	Concho Bill Spr.	Inorganic O, H & N isotopes	-	-	Black River
13th Field Trip, November 4-5, 2014 – Towne & Spindler									
SRB-50	A(5-27)10dad spring	33.839500 -109.472983	-	79581	Slade Spring	Inorganic O,H & N Isotopes	-	-	Black River
SRB-51/52 split	A(5-28)03abd spring	33.861981 -109.372242	-	79582	U. Cienega Redondo	Inorganic, Radiochem Radon, O,H,N isotope	-	-	Black River
SRB-53	A(5-29)05abc spring	33.854433 -109.315617	-	79583	Three Forks Spr	Inorganic O,H & N Isotopes	-	-	Black River
SRB-54	A(5-30)16add spring	33.828850 -109.178000	-	79584	Bear Spring	Inorganic O,H & N Isotopes	-	-	Black River
SRB-55	A(4-29)34ddd submersible	33.642217 -109.324167	537589	58673	FS Han Md Campgrnd	Inorganic, Radiochem Radon, O,H,N isotope	110’	52’	Black River
SRB-56	A(3-29)21bab spring	33.59760 -109.35220	-	79586	Up. Cache Cienega	Inorganic O,H & N Isotopes	-	-	Black River
14th Field Trip, August 10-11, 2015 – Towne & Boettcher									
SRB-57/58 split	A(9-14)04cad submersible	34.14849 -110.91710	534360	80141	Heairet Well	Inorganic, Radiochem O,H, N isotope	200’	13’	Salt River Cyn
SRB-59/16 time trend	A(9-14)30aad submersible	34.09892 -110.94415	600863	59454	North Well	Inorganic, Radiochem O,H, N isotope	135’	22’	Salt River Cyn
SRB-61	A(9-14)30ab submersible	34.10082 -110.94838	644244	80161	Alborn Well	Inorganic O,H, N isotope	55’	20’	Salt River Cyn
SRB-62	A(9-13)25dcd submersible	34.08716 -110.96490	624214	80162	Harris Well	Inorganic, Radiochem O,H, N isotope	130’	70’	Salt River Cyn
SRB-63	A(9-15)05ccc spring	34.14560 -110.83743	-	80163	Bottle Spring	Inorganic O,H, N isotope	-	-	Salt River Cyn
SRB-64	A(9-15)08ccb spring	34.13414 -110.83707	-	80164	Carroll Spring	Inorganic O,H, N isotope	-	-	Salt River Cyn
SRB-65	A(9-14)20dbc submersible	34.10625 -110.93253	-	80167	Pst Office Well	Inorganic, Radiochem O,H, N isotope	125’	18’	Salt River Cyn
SRB-66/67 duplicate	A(9-14)21bbb artesian	34.11565 -110.92361	801938	80165	Jones Artesian	Inorganic, Radiochem O,H, N isotope	120’	0’	Salt River Cyn
SRB-68	A(9-13)26caa submersible	34.09393 -110.98641	650655	80166	Cooper Deep Well	Inorganic, Radiochem O,H, N isotope	280’	180’	Salt River Cyn
15th Field Trip, September 21-22, 2015 – Towne & Boettcher (Equipment Blank SRB-72)									
SRB-69	A(9-13)14ddd submersible	34.11626 -110.97965	556012	80286	Wade Well	Inorganic, Radiochem Radon, O,H,N isotope	285’	80’	Salt River Cyn
SRB-70	A(6-13)25cca spring	33.82849 -110.97928	-	80287	Rose Creek Spring	Inorganic O,H, N isotope	-	-	Salt River Lakes
SRB-71	A(2-15)02dbb spring	33.54247 -110.79537	-	80288	Procopio Spring	Inorganic, Radiochem O,H, N isotope	-	-	Salt River Lakes
SRB-73	A(5-13)12aca submersible	33.79288 -110.97164	628109	80289	ADOT Pk Crk Well	Inorganic, Radiochem Radon, O,H,N isotope	300’	56’	Salt River Lakes
SRB-74	A(3-13)14baa submersible	33.60990 -111.99911	620962	80290	Tucker Dm Well	Inorganic, Radiochem Radon, O,H,N isotope	300’	160’	Salt River Lakes
SRB-75	A(3-13)11cdd submersible	33.61210 -111.00011	620960	80291	Tucker Old Arena Well	Inorganic O,H,N isotope	100’	40’	Salt River Lakes
SRB-76/77 duplicate	A(3-13)15aaa submersible	33.60955 -111.00808	917122	80292	Hanson New Well	Inorganic, Radiochem Radon, O,H,N isotope	340’	61’	Salt River Lakes

Appendix A. Data for Sample Sites, Salt River Basin, 2001-2015

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Sub-basin
16th Field Trip, October 21-22, 2015 – Towne & Spindler									
SRB-78	D(2-15)04cbb spring	33.28699 -110.82520	-	80366	Ferndell Spring	Inorganic, Radiochem Radon, O,H,N isotope	-	-	Salt River Lakes
SRB-79	A(4-17)15ada spring	33.69155 -110.55008	-	80367	Carol Spring #4	Inorganic O,H, N isotope	-	-	Salt River Lakes
SRB-80	A(3-16)05ccc spring	33.62613 -110.70498	-	80368	Ltl Walnut Spring	Inorganic, Radiochem O,H, N isotope	-	-	Salt River Lakes
SRB-81	A(2-15)18dab submersible	33.87528 -110.86193	564374	80346	H+E Well #1	Inorganic, Radiochem Radon, O,H,N isotope	610’	287’	Salt River Lakes
17th Field Trip, November 10, 2015 – Towne & Boettcher									
SRB-82	A(2-14)11ccc windmill	33.524367 -110.910333	802086	80436	Devore WashWell	Inorganic, Radiochem O,H,N isotope	220’	70’	Salt River Lakes
SRB-83	A(3-14)05add submersible	33.631467 -110.938100	596667	80437	Rock HouseStore	Inorganic, Radiochem Radon, O,H,N isotope	80’	40’	Salt River Lakes

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015

Site #	MCL Exceedances	Temp (ºC)	pH-field (su)	pH-lab (su)	SC-field (µS/cm)	SC-lab (µS/cm)	TDS (mg/L)	Hard (mg/L)	Hard - cal (mg/L)	Turb (ntu)
SRB-1	TDS, Cl	20.6	7.34	*7.4*	3040	3000	**1650**	340	330	*3.2*
SRB-2	-	25.8	7.73	*7.6*	552	500	310	240	240	0.03
SRB-3/3D	pH, As	25.8	**9.29**	*9.1*	478	465	300	ND	ND	0.215
SRB-4/4S	-	24.1	7.95	*8.1*	384	370	230	130	130	0.83
SRB-5/5D	TDS, Zn	-	-	*7.65*	-	985	**585**	340	330	5.3
SRB-6	-	-	-	*7.8*	-	700	400	330	330	0.10
SRB-7	TDS	-	-	*7.7*	-	1100	**650**	370	360	0.98
SRB-8/8D	TDS, Cl, Mn	20.7	7.16	*7.65*	1760	1800	**925**	245	240	2.1
SRB-9	As, **F**	38.7	7.85	*8.0*	500	490	320	70	72	0.07
SRB-12	-	-	-	*8.3*	-	130	92	34	34	0.00
SRB-13	-	-	-	*7.9*	-	150	110	63	63	0.08
SRB-14/14S	Fe, Mn	-	-	*7.73*	-	410	245	160	150	6.05
SRB-15/15D	-	13.4	7.28	*7.75*	470	530	315	240	240	0.135
SRB-16/16S/59	-	18.2	7.32	*7.54*	393	450	255	195	206.5	0.01
SRB-17	Fe, Mn	13.5	6.93	*7.2*	398	450	270	230	210	14
SRB-18	-	19.5	7.36	7.6	560	560	360	270	260	0.01
SRB-19	-	12.5	7.28	*7.7*	427	490	290	240	230	1.7
SRB-19A	As	10.4	7.29	*7.2*	200	240	130	110	110	0.48
SRB-20/20D	-	14.8	7.13	*6.9*	215	215	150	76	72	2.8
SRB-21/21S	TDS, As	18.4	7.99	8.12	1032	1100	**625**	41.5	37	0.12
SRB-22	-	21.3	7.56	*7.4*	451	450	260	200	190	0.04
SRB-23	-	22.6	7.43	*7.2*	590	580	330	250	240	0.04
SRB-24	As, Fe	11.3	8.47	*8.1*	497	507	280	220	200	3.0
SRB-25	TDS, Fe	22.2	7.58	*7.6*	880	860	**520**	430	380	8.5
SRB-26/26D	Gross alpha, U	19.8	7.22	*7.65*	776	800	470	330	340	0.71
SRB-27	Gross alpha	-	-	*7.4*	-	540	310	220	220	3.2
SRB-28/28D	F, Gross alpha, U	26.9	7.38	*7.55*	673	720	405	280	280	0.03
SRB-29	-	28.5	7.40	*7.4*	650	680	380	330	330	0.00

italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015

Site #	MCL Exceedances	Temp (ºC)	pH-field (su)	pH-lab (su)	SC-field (µS/cm)	SC-lab (µS/cm)	TDS-f (mg/L)	TDS (mg/L)	Hard (mg/L)	Turb (ntu)
SRB-30	-	22.5	7.56	*7.4*	546	580	-	260	260	1.2
SRB-31	-	22.7	7.51	*7.4*	612	650	-	400	280	0.20
SRB-32/32S	TDS, SO4	22.4	7.86	*7.67*	1339	1400	-	**860**	320	2.35
SRB-33	TDS	25.8	7.58	*7.6*	833	870	-	**540**	360	0.49
SRB-34	As	27.5	7.46	*7.4*	624	650	-	360	300	2.1
SRB-35	TDS, SO_4	24.1	7.10	*7.2*	1704	1800	-	**1400**	970	0.04
SRB-36	-	13.6	7.64	*7.2*	108	110	-	83	45	4.4
SRB-37/37D	-	13.3	7.29	*7.65*	281	305	-	180	140	0.035
SRB-39	-	15.9	7.37	*7.2*	585	570	-	340	280	0.11
SRB-40	-	21.3	7.40	*7.2*	716	700	-	410	300	0.46
SRB-41	Gross alpha	20.9	8.31	*8.4*	433	390	-	240	38	8.1
SRB-42a	-	20.2	8.30	*8.4*	486	410	-	250	41	2.4
SRB-42b	-	12.1	7.43	*7.10*	116	99.1	76	73	41.3	ND
SRB-43	-	12.6	7.09	*6.95*	108	101	70	78	35.8	ND
SRB-44	Al, Fe	8.8	6.81	*7.20*	152	135	99	166	65.3	35.8
SRB-45	-	11.7	7.29	7.78	190	179	124	118	83.8	ND
SRB-46	-	9.1	7.41	*6.93*	12	146	8	100	63.4	ND
SRB-47	Al	10.2	7.46	*7.30*	142	127	92	93	59.8	1.7
SRB-48	-	8.3	7.36	6.98	130	114	85	90	49.7	2.6
SRB-49	Mn	12.4	7.19	*6.94*	92	78.9	60	59	ND	2.4
SRB-50	-	11.0	6.56	*7.14*	92	33.1	60	51	ND	ND
SRB-51/52	pH, Al, Radon	7.97	**6.39**	*6.63*	133	109	87	82	50	3.0
SRB-53	-	15.2	7.60	*8.30*	159	127	103	81	51.4	ND
SRB-54	-	5.48	7.51	*6.76*	142	122	92	86	58.2	4.4
SRB-55	-	7.16	7.33	*7.10*	268	176	174	101	80.1	ND
SRB-56	-	6.38	7.04	*6.70*	197	98.5	128	41	40.7	0.73
SRB-57/58	-	20.4	6.52	*6.675*	293	285	190	176	123	ND
SRB-61	-	19.1	7.59	*7.71*	448	462	291	281	227	ND

italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015

Site #	MCL Exceedances	Temp (ºC)	pH-field (su)	pH-lab (su)	SC-field (µS/cm)	SC-lab (µS/cm)	TDS-f (mg/L)	TDS (mg/L)	Hard (mg/L)	Turb (ntu)
SRB-62	-	17.8	7.51	*7.60*	388	397	252	276	189	ND
SRB-63	-	22.9	8.26	*8.52*	339	331	220	204	172	2.4
SRB-64	-	20.0	7.56	*7.74*	521	533	338	302	292	0.83
SRB-65	-	18.6	7.03	*7.14*	587	609	381	353	304	ND
SRB-66/67	-	17.2	7.55	*7.59*	341	347	221	208.5	173	ND
SRB-68	-	20.6	7.49	*7.59*	344	346	223	211	175	ND
SRB-69	Al	18.5	8.20	*7.33*	332	273	216	200	108	ND
SRB-70	-	19.0	7.19	*7.32*	575	524	374	320	274	ND
SRB-71	TDS	23.2	7.18	*7.30*	867	820	564	**520**	385	ND
SRB-73	TDS, As	17.7	6.99	*7.32*	893	843	580	**524**	416	ND
SRB-74	-	22.1	7.83	*7.99*	469	416	305	263	172	ND
SRB-75	TDS, SO_4	20.6	7.14	*7.35*	984	958	640	**722**	474	1.4
SRB-76/77	pH, As	25.1	**9.01**	*9.04*	685	635.5	445	416	ND	ND
SRB-78	-	11.1	6.73	*7.22*	204	192	133	135	68.8	ND
SRB-79	pH, Fe, Mn	13.6	**6.17**	6.43	156	131	101	188	42.1	71.3
SRB-80	-	17.0	6.98	*7.62*	480	439	312	261	177	ND
SRB-81	-	21.6	7.67	*7.97*	419	385	272	234	154	6.5
SRB-82	TDS, U	17.6	7.89	7.94	1157	1190	752	**782**	582	-
SRB-83	TDS, Cl	20.1	7.18	*8.01*	3190	3370	2074	**1700**	385	-

italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	T. Alk (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
SRB-1	89	27	490	8.5	200	240	ND	**710**	120
SRB-2	60	22	12	2.4	220	270	ND	12	20
SRB-3/3D	1.5	ND	110	0.695	192.5	186	23.5	19	9.65
SRB-4/4S	39	8	31	1.7	153	187	ND	9.8	15
SRB-5/5D	78	32	78.5	1.9	270	330	ND	94.5	98
SRB-6	78	32	23	1.3	300	370	ND	27	23
SRB-7	96	30	86	2.4	210	260	ND	160	120
SRB-8/8D	65.5	18	245	5.9	140	170	ND	**385**	71
SRB-9	27	1.0	72	3.6	120	146	ND	42	50
SRB-12	9.7	2.4	13	1.5	61	74	ND	1.3	ND
SRB-13	15	6.2	4.0	1.9	62	76	ND	3.5	4.0
SRB-14/14S	41.5	12	32	0.52	200	240	ND	4.1	11.5
SRB-15/15D	49	27.9	17.95	2.735	240	290	ND	10.4	15
SRB-16/16S/59	60.6	12.9	10.4	1.13	212	260.5	ND	5.5	2.05
SRB-17	37	28	8.7	2.7	210	260	ND	5.2	13
SRB-18	62	26	15	3.0	240	290	ND	14	33
SRB-19	41	32	9.4	2.0	240	290	ND	3.9	12
SRB-19A	32	8.4	2.2	0.96	110	134	ND	1.9	3.9
SRB-20/20D	21.5	4.35	15	1.2	84	100	ND	5.95	16
SRB-21/21S	10.5	3.15	215	1.25	350	430	ND	14.5	135
SRB-22	55	13	19	2.0	200	240	ND	15	19
SRB-23	69	17	30	2.4	250	300	ND	21	32
SRB-24	56	14	29	2.4	210	256	ND	33	8.7
SRB-25	100	31	40	2.8	290	350	ND	20	140
SRB-26/26D	74	37.5	43	2.0	345	420	ND	19	59
SRB-27	61	17	25	1.5	240	290	ND	13	25
SRB-28/28D	54	36	43	2.3	270	330	ND	25	66.5
SRB-29	70	38	20	0.54	330	400	ND	13	29

italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	T. Alk (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
SRB-30	62	26	20	1.5	260	320	ND	26	12
SRB-31	73	22	23	3.6	180	220	ND	22	120
SRB-32/32S	70	33	125	4.3	100	120	ND	190	**280**
SRB-33	89	35	42	3.1	250	300	ND	36	170
SRB-34	64	35	22	2.8	280	340	ND	23	36
SRB-35	260	73	48	5.6	150	180	ND	77	**790**
SRB-36	9.6	5.1	3.3	1.2	45	55	ND	2.6	ND
SRB-37	32	15	7.85	1.05	150.5	183.5	ND	2.0	ND
SRB-39	74	27	4.4	1.7	280	340	ND	3.9	14
SRB-40	47	48	28	3.1	300	370	ND	10	56
SRB-41	16	1.2	75	2.1	210	250	3.3	ND	1.2
SRB-42a	13	2.1	81	2.3	220	260	3.9	6.0	1.8
SRB-42b	10.8	ND	5.17	ND	38.1	46.5	ND	2.4	8.1
SRB-43	7.63	ND	6.63	0.782	43.6	53.2	ND	0.89	4.8
SRB-44	14.7	6.95	3.44	1.19	65.3	79.7	ND	2.0	9.9
SRB-45	18.4	9.19	4.84	1.22	87.1	106.3	ND	2.4	4.7
SRB-46	13.6	7.15	5.64	0.699	71.3	87.0	ND	1.7	6.1
SRB-47	14.5	5.74	3.67	0.580	62.8	76.6	ND	2.3	3.3
SRB-48	14.1	ND	2.98	1.25	49.5	60.4	ND	1.8	5.5
SRB-49	7.38	ND	3.26	ND	29.7	36.2	ND	1.4	5.3
SRB-50	ND	ND	2.08	ND	21.4	26.1	ND	0.81	2.4
SRB-51/52	12.9	ND	3.48	ND	44	53.7	ND	1.5	5.2
SRB-53	12.9	ND	7.01	1.84	61.5	75	ND	0.92	0.70
SRB-54	14.4	5.40	3.39	1.01	48	58.6	ND	2.2	7.6
SRB-55	19.2	7.80	4.55	ND	62	75.6	ND	7.9	5.0
SRB-56	9.70	ND	3.45	ND	34	41.5	ND	3.0	4.6
SRB-57/58	31.3	11.25	7.04	1.074	75.8	92.5	ND	19.7	12.7
SRB-61	69.1	13.3	10.1	0.724	194	237	ND	20.3	4.1

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bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	T. Alk (mg/L)	Bicarbonate (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)
SRB-62	66.6	5.5	8.27	0.25	152	185	ND	15.5	7.1
SRB-63	26.9	25.4	9.83	2.19	174	212	ND	5.0	2.5
SRB-64	65.3	31.2	9.36	3.65	283	345	ND	4.5	11.2
SRB-65	88.9	20.0	15.7	0.896	307	375	ND	12.6	8.7
SRB-66/67	49.0	12.25	8.98	0.838	182.5	222	ND	3.8	1.55
SRB-68	47.7	13.6	8.14	0.610	178	217	ND	4.8	1.5
SRB-69	27.9	9.41	13.5	0.940	95.1	116	ND	20.6	15.6
SRB-70	52.8	34.6	11.8	2.86	277	338	ND	5.8	19.6
SRB-71	79.6	45.3	40.2	1.42	424	517	ND	30.3	45.1
SRB-73	73.1	56.7	25.9	6.24	416	508	ND	21.2	78.2
SRB-74	31.0	23.0	26.2	2.10	177	216	ND	11.0	54.6
SRB-75	124	39.8	32.1	2.71	190	232	ND	29.3	**289**
SRB-76/77	ND	ND	167	0.713	302	299	35	16.4	23.3
SRB-78	21.3	ND	10.0	1.30	77.8	95	ND	3.6	13.0
SRB-79	12.0	ND	3.29	2.69	26	32	ND	2.8	23.9
SRB-80	34.7	21.9	21.2	1.56	196	239	ND	9.5	20.4
SRB-81	44.5	10.5	15.9	1.78	172	210	ND	8.6	17.0
SRB-82	134	60.0	50.5	2.51	418	510	ND	71.4	203
SRB-83	103	31.1	547	9.20	244	298	ND	**877**	93.0

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Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	Nitrate-N (mg/L)	δ^{15}N ($^0/_{00}$)	Nitrite-N (mg/L)	TKN (mg/L)	Ammonia (mg/L)	T. Phos. (mg/L)	SAR (value)	Irrigation Quality	Alum (mg/L)	Strontium (mg/L)
SRB-1	0.035	-	ND	ND	ND	0.032	11.7	C4-S3	ND	-
SRB-2	0.88	-	ND	ND	ND	ND	0.3	C2-S1	ND	-
SRB-3/3D	1.9	-	ND	ND	ND	0.036	24.7	C2-S4	ND	-
SRB-4/4S	0.43	-	ND	ND	ND	ND	1.2	C2-S1	ND	-
SRB-5/5D	ND	-	ND	ND	ND	0.070	1.9	C3-S1	ND	-
SRB-6	0.36	-	ND	ND	ND	ND	0.6	C2-S1	ND	-
SRB-7	0.42	-	ND	ND	ND	0.051	2.0	C3-S1	ND	-
SRB-8/8D	ND	-	ND	0.0755	ND	0.052	7.1	C3-S2	ND	-
SRB-9	0.66	-	ND	ND	ND	ND	3.7	C2-S1	ND	-
SRB-12	0.93	-	ND	ND	ND	ND	1.0	C1-S1	ND	-
SRB-13	0.83	-	ND	ND	ND	0.081	0.2	C1-S1	ND	-
SRB-14/14S	ND	-	ND	ND	ND	0.14	1.1	C2-S1	ND	-
SRB-15/15D	0.13	-	ND	ND	ND	0.36	0.5	C2-S1	ND	-
SRB-16/16S/59	0.46	4.6	ND	ND	ND	ND	0.3	C2-S1	ND	0.204
SRB-17	ND	-	ND	ND	ND	ND	0.3	C2-S1	ND	-
SRB-18	0.79	-	ND	0.095	ND	ND	0.4	C2-S1	ND	-
SRB-19	0.87	-	ND	ND	ND	ND	0.3	C2-S1	ND	-
SRB-19A	ND	-	ND	ND	ND	0.052	0.0	C1-S1	ND	-
SRB-20/20D	0.031	-	ND	ND	ND	0.071	0.8	C1-S1	ND	-
SRB-21/21S	ND	-	ND	ND	ND	ND	15.7	C3-S4	ND	-
SRB-22	1.0	-	ND	ND	ND	ND	0.6	C2-S1	ND	-
SRB-23	0.75	-	ND	ND	ND	ND	0.8	C2-S1	ND	-
SRB-24	1.1	-	ND	1.8	ND	0.27	0.9	C2-S1	ND	-
SRB-25	1.2	-	ND	ND	ND	0.030	0.9	C3-S1	ND	-
SRB-26/26D	0.24	-	ND	ND	ND	ND	1.0	C3-S1	ND	-
SRB-27	0.93	-	ND	0.085	0.054	0.025	0.7	C2-S1	ND	-
SRB-28/28D	1.7	-	ND	ND	ND	ND	1.1	C2-S1	ND	-
SRB-29	ND	-	ND	0.085	ND	0.026	0.5	C2-S1	ND	-

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Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	Nitrate-N (mg/L)	δ^{15}N ($^0/_{00}$)	Nitrite-N (mg/L)	TKN (mg/L)	Ammonia (mg/L)	T. Phos. (mg/L)	SAR (value)	Irrigation Quality	Alum (mg/L)	Strontium (mg/L)
SRB-30	ND	-	ND	ND	ND	ND	0.5	C2-S1	ND	-
SRB-31	3.0	-	ND	ND	ND	ND	0.6	C2-S1	ND	-
SRB-32/32S	0.1025	-	ND	0.08/1.1	ND	ND	4.0	C3-S1	ND	-
SRB-33	0.41	-	ND	0.082	ND	ND	1.0	C2-S1	ND	-
SRB-34	0.44	-	ND	0.13	ND	ND	0.5	C2-S1	ND	-
SRB-35	0.55	-	ND	0.21	ND	ND	0.7	C3-S1	ND	-
SRB-36	0.18	-	ND	0.098	ND	0.14	0.2	C1-S1	ND	-
SRB-37	0.24	-	ND	ND	ND	0.20	0.3	C2-S1	ND	-
SRB-39	0.11	-	ND	ND	ND	ND	0.1	C2-S1	ND	-
SRB-40	ND	-	ND	ND	ND	0.021	0.7	C2-S1	ND	-
SRB-41	0.025	-	ND	ND	-	ND	4.9	C2-S1	-	-
SRB-42a	ND	-	ND	ND	-	ND	5.5	C2-S1	-	-
SRB-42b	ND	2.4	ND	0.27	ND	0.11	0.4	C1-S1	ND	0.149
SRB-43	0.18	4.4	ND	ND	ND	0.070	0.5	C1-S1	ND	0.089
SRB-44	0.81	4.1	ND	ND	ND	0.19	0.2	C1-S1	**5.09**	0.125
SRB-45	0.39	5.1	ND	ND	ND	0.071	0.2	C1-S1	ND	0.180
SRB-46	0.52	5.4	ND	0.20	ND	0.038	0.3	C1-S1	ND	0.156
SRB-47	0.12	5.1	ND	ND	ND	0.069	0.2	C1-S1	**0.246**	0.151
SRB-48	1.3	4.6	ND	ND	ND	0.17	0.2	C1-S1	ND	0.0986
SRB-49	ND	4.1	ND	ND	ND	0.34	0.3	C1-S1	ND	0.0990
SRB-50	ND	3.6	ND	ND	ND	ND	0.2	C1-S1	ND	0.0480
SRB-51/52	0.23	5.1	ND	ND	ND	0.028	0.3	C1-S1	**0.285**	0.150
SRB-53	0.15	4.3	ND	ND	ND	0.040	0.5	C1-S1	ND	0.0571
SRB-54	ND	2.8	ND	ND	ND	0.077	0.2	C1-S1	ND	0.200
SRB-55	1.7	12.3	ND	ND	ND	0.065	0.2	C1-S1	ND	0.172
SRB-56	0.29	5.5	ND	ND	ND	0.085	0.3	C1-S1	ND	0.163
SRB-57/58	5.95	12.8	ND	ND	ND	ND	0.2	C2-S1	ND	0.1175
SRB-61	3.4	12.7	ND	ND	ND	ND	0.3	C2-S1	ND	0.218

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bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	Nitrate-N (mg/L)	$\delta^{15}N$ ($^{0}/_{00}$)	Nitrite-N (mg/L)	TKN (mg/L)	Ammonia (mg/L)	T. Phos. (mg/L)	SAR (value)	Irrigation Quality	Alum (mg/L)	Strontium (mg/L)
SRB-62	5.5	11.1	ND	ND	ND	0.025	0.3	C2-S1	ND	0.0992
SRB-63	0.05	0.7	ND	ND	ND	0.077	0.3	C2-S1	ND	0.145
SRB-64	0.05	1.4	ND	ND	ND	0.033	0.2	C2-S1	ND	0.235
SRB-65	0.24	9.9	ND	ND	ND	ND	0.4	C2-S1	ND	0.511
SRB-66/67	0.195	4.7	ND	ND	ND	ND	0.3	C2-S1	ND	0.170
SRB-68	0.73	3.8	ND	ND	ND	ND	0.3	C2-S1	ND	0.166
SRB-69	2.3	12.5	ND	ND	ND	0.031	0.6	C2-S1	**0.2230**	0.141
SRB-70	ND	4.4	ND	0.22	ND	ND	0.3	C2-S1	ND	0.252
SRB-71	ND	10.4	ND	ND	ND	ND	0.9	C3-S1	ND	0.297
SRB-73	ND	3.6	ND	ND	ND	ND	0.6	C3-S1	ND	0.154
SRB-74	0.44	4.5	ND	ND	ND	ND	0.9	C2-S1	ND	0.855
SRB-75	0.81	7.2	ND	ND	ND	0.031	0.6	C3-S1	ND	0.807
SRB-76/77	ND	5.1	ND	ND	ND	0.0515	102.2	C2-S4	ND	0.02155
SRB-78	0.10	4.6	ND	ND	ND	0.021	0.5	C2-S1	ND	0.139
SRB-79	0.51	9.6	0.16	3.0	1.3	0.47	0.2	C2-S1	0.267	0.0522
SRB-80	0.53	4.8	ND	0.30	ND	0.041	0.7	C2-S1	ND	0.161
SRB-81	0.99	4.7	ND	0.30	ND	0.023	0.6	C2-S1	ND	0.299
SRB-82	0.27	5.0	ND	1.4	ND	0.022	0.9	C3-S1	ND	0.677
SRB-83	ND	6.7	ND	0.64	ND	0.033	12.1	C4-S3	ND	1.01

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bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	**Antimony** (mg/L)	**Arsenic** (mg/L)	**Barium** (mg/L)	**Beryllium** (mg/L)	**Boron** (mg/L)	**Cadmium** (mg/L)	**Chromium** (mg/L)	**Copper** (mg/L)	**Fluoride** (mg/L)
SRB-1	ND	ND	ND	ND	0.24	ND	ND	ND	0.21
SRB-2	ND	ND	ND	ND	ND	ND	ND	ND	0.24
SRB-3/3D	ND	**0.019**	ND	ND	0.12	ND	0.023	ND	0.625
SRB-4/4S	ND	ND	0.21	ND	ND	ND	ND	ND	1.8
SRB-5/5D	ND	ND	ND	ND	0.20	ND	ND	ND	0.44
SRB-6	ND	ND	ND	ND	ND	ND	ND	ND	0.31
SRB-7	ND	ND	ND	ND	ND	ND	ND	ND	1.2
SRB-8/8D	ND	ND	ND	ND	0.14	ND	ND	ND	0.36
SRB-9	ND	**0.16**	ND	ND	0.11	ND	ND	ND	**4.0**
SRB-12	ND	ND	ND	ND	ND	ND	ND	ND	0.14
SRB-13	ND	ND	ND	ND	ND	ND	ND	ND	0.069
SRB-14/14S	ND	ND	ND	ND	ND	ND	ND	ND	0.22
SRB-15/15D	ND	ND	ND	ND	ND	ND	ND	ND	0.12
SRB-16/16S/59	ND	0.0036	0.102	ND	ND	ND	ND	ND	0.29
SRB-17	ND	ND	ND	ND	ND	ND	ND	ND	0.082
SRB-18	ND	ND	ND	ND	ND	ND	ND	ND	0.24
SRB-19	ND	ND	ND	ND	ND	ND	ND	ND	0.077
SRB-19A	ND	**0.011**	ND	ND	ND	ND	ND	ND	ND
SRB-20/20D	ND	ND	ND	ND	ND	ND	ND	ND	0.16
SRB-21/21S	ND	**0.0175**	ND	ND	0.16	ND	ND	ND	**
SRB-22	ND	ND	ND	ND	ND	ND	ND	ND	0.28
SRB-23	ND	ND	ND	ND	ND	ND	ND	ND	0.32
SRB-24	ND	**0.015**	ND	ND	ND	0.0018	ND	0.13	0.75
SRB-25	ND	ND	ND	ND	ND	ND	ND	0.11	0.40
SRB-26/26D	ND	ND	ND	ND	ND	ND	ND	ND	0.965
SRB-27	ND	ND	ND	ND	ND	ND	ND	ND	0.80
SRB-28/28D	ND	ND	ND	ND	ND	ND	ND	ND	**2.9**
SRB-29	ND	ND	ND	ND	ND	ND	ND	ND	0.22

italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level
** - data did not meet QA/QC standards

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	Antimony (mg/L)	Arsenic (mg/L)	Barium (mg/L)	Beryllium (mg/L)	Boron (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Fluoride (mg/L)
SRB-30	ND	ND	ND	ND	ND	ND	ND	ND	0.21
SRB-31	ND	ND	ND	ND	ND	ND	ND	ND	0.21
SRB-32/32S	ND	ND	0.11	ND	ND	ND	ND	ND	0.11
SRB-33	ND	ND	ND	ND	ND	ND	ND	ND	0.39
SRB-34	ND	**0.011**	ND	ND	ND	ND	ND	ND	0.33
SRB-35	ND	ND	ND	ND	ND	ND	ND	ND	0.18
SRB-36	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-37	ND	ND	ND	ND	ND	ND	ND	ND	0.21
SRB-39	ND	ND	ND	ND	ND	ND	ND	ND	0.22
SRB-40	ND	ND	ND	ND	ND	ND	ND	ND	0.74
SRB-41	ND	ND	ND	ND	ND	ND	ND	ND	0.29
SRB-42a	ND	ND	ND	ND	ND	ND	ND	ND	0.16
SRB-42b	ND	ND	0.0224	ND	ND	ND	ND	ND	ND
SRB-43	ND	ND	0.0051	ND	ND	ND	ND	ND	ND
SRB-44	ND	ND	0.0068	ND	ND	ND	ND	ND	ND
SRB-45	ND	ND	0.0037	ND	ND	ND	ND	ND	0.21
SRB-46	ND	ND	0.0079	ND	ND	ND	ND	ND	ND
SRB-47	ND	ND	0.0046	ND	ND	ND	ND	ND	ND
SRB-48	ND	ND	0.0070	ND	ND	ND	ND	ND	ND
SRB-49	ND	ND	0.0332	ND	ND	ND	ND	ND	ND
SRB-50	ND	ND	0.0162	ND	ND	ND	ND	ND	ND
SRB-51/52	ND	ND	0.0106	ND	ND	ND	ND	ND	ND
SRB-53	ND	0.0010	ND	ND	ND	ND	ND	ND	0.10
SRB-54	ND	ND	0.0927	ND	ND	ND	ND	ND	ND
SRB-55	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-56	ND	ND	0.0093	ND	ND	ND	ND	ND	ND
SRB-57/58	ND	ND	0.04225	ND	ND	ND	ND	ND	0.061
SRB-61	ND	0.0021	0.109	ND	ND	ND	ND	ND	0.29

italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	Antimony (mg/L)	Arsenic (mg/L)	Barium (mg/L)	Beryllium (mg/L)	Boron (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Fluoride (mg/L)
SRB-62	ND	0.0072	0.0960	ND	ND	ND	ND	ND	0.15
SRB-63	ND	ND	0.0132	ND	ND	ND	ND	ND	ND
SRB-64	ND	ND	0.0298	ND	ND	ND	ND	ND	ND
SRB-65	ND	0.0012	0.144	ND	ND	ND	ND	ND	0.18
SRB-66/67	ND	ND	0.0732	ND	ND	ND	ND	ND	0.31
SRB-68	ND	ND	0.0923	ND	ND	ND	ND	ND	0.26
SRB-69	ND	0.0034	0.0096	ND	ND	ND	ND	0.0112	0.13
SRB-70	ND	ND	0.0326	ND	ND	ND	ND	ND	ND
SRB-71	ND	0.0016	0.475	ND	ND	ND	ND	ND	0.31
SRB-73	ND	**0.0100**	0.0238	ND	ND	ND	ND	0.0057	0.21
SRB-74	ND	0.0014	0.0272	ND	ND	ND	ND	ND	0.35
SRB-75	ND	0.0015	0.0944	ND	ND	ND	ND	ND	0.25
SRB-76/77	ND	**0.120**	0.0011	ND	0.3675	ND	ND	ND	0.99
SRB-78	ND	ND	0.0387	ND	ND	ND	ND	ND	ND
SRB-79	ND	0.0055	0.0771	ND	ND	ND	ND	ND	ND
SRB-80	ND	0.0071	0.0271	ND	ND	ND	ND	ND	0.43
SRB-81	ND	0.0032	0.0031	ND	ND	ND	ND	ND	0.15
SRB-82	ND	0.0014	0.101	ND	ND	ND	ND	0.0163	0.47
SRB-83	ND	0.0030	0.0921	ND	0.295	ND	ND	ND	0.25

italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	**Iron** (mg/L)	**Lead** (mg/L)	**Manganese** (mg/L)	**Mercury** (mg/L)	**Nickel** (mg/L)	**Selenium** (mg/L)	**Silver** (mg/L)	**Thallium** (mg/L)	**Zinc** (mg/L)
SRB-1	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-2	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-3/3D	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-4/4S	ND	ND	ND	ND	ND	ND	ND	ND	0.14
SRB-5/5D	ND	ND	ND	ND	ND	ND	ND	ND	**5.75**
SRB-6	ND	0.0050	ND	ND	ND	ND	ND	ND	ND
SRB-7	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-8/8D	0.11	ND	**0.415**	ND	ND	ND	ND	ND	0.054
SRB-9	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-12	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-13	ND	ND	ND	ND	ND	ND	ND	ND	0.056
SRB-14/14S	**0.875**	ND	**0.215**	ND	ND	ND	ND	ND	ND
SRB-15/15D	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-16/16S/59	ND	ND	ND	ND	ND	0.0013	ND	ND	ND
SRB-17	**0.89**	ND	**0.18**	ND	ND	ND	ND	ND	1.4
SRB-18	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-19	ND	ND	ND	ND	ND	ND	ND	ND	0.059
SRB-19A	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-20/20D	ND	ND	ND	ND	ND	ND	ND	ND	1.35
SRB-21/21S	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-22	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-23	ND	ND	ND	ND	ND	ND	ND	ND	0.53
SRB-24	**2.3**	ND	ND	ND	ND	ND	ND	ND	0.84
SRB-25	**1.4**	ND	ND	ND	ND	ND	ND	ND	0.31
SRB-26/26D	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-27	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-28/28D	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-29	ND	ND	ND	ND	ND	ND	ND	ND	ND

italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	Iron (mg/L)	Lead (mg/L)	Manganese (mg/L)	Mercury (mg/L)	Nickel (mg/L)	Selenium (mg/L)	Silver (mg/L)	Thallium (mg/L)	Zinc (mg/L)
SRB-30	ND	0.0060	ND	ND	ND	ND	ND	ND	ND
SRB-31	ND	ND	ND	ND	ND	ND	ND	ND	0.10
SRB-32/32S	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-33	ND	ND	ND	ND	ND	ND	ND	ND	0.18
SRB-34	ND	ND	ND	ND	ND	ND	ND	ND	0.061
SRB-35	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-36	0.13	ND	ND	ND	ND	ND	ND	ND	ND
SRB-37	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-39	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-40	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-41	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-42a	0.20	ND	ND	ND	ND	ND	ND	ND	ND
SRB-42b	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-43	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-44	**2.47**	0.00060	0.0165	ND	0.0054	ND	ND	ND	ND
SRB-45	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-46	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-47	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-48	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-49	0.238	ND	**0.0883**	ND	ND	ND	ND	ND	ND
SRB-50	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-51/52	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-53	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-54	ND	ND	0.0313	ND	ND	ND	ND	ND	ND
SRB-55	ND	ND	ND	ND	ND	ND	ND	ND	0.0516
SRB-56	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-57/58	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-61	ND	ND	ND	ND	ND	ND	ND	ND	ND

italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	**Iron** (mg/L)	**Lead** (mg/L)	**Manganese** (mg/L)	**Mercury** (mg/L)	**Nickel** (mg/L)	**Selenium** (mg/L)	**Silver** (mg/L)	**Thallium** (mg/L)	**Zinc** (mg/L)
SRB-62	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-63	0.268	ND	0.0159	ND	ND	ND	ND	ND	ND
SRB-64	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-65	ND	0.00064	ND	ND	ND	ND	ND	ND	ND
SRB-66/67	ND	ND	ND	ND	ND	ND	ND	ND	0.02125
SRB-68	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-69	ND	ND	ND	ND	ND	0.0029	ND	ND	ND
SRB-70	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-71	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-73	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-74	ND	ND	ND	ND	ND	0.0014	ND	ND	ND
SRB-75	0.208	ND	ND	ND	ND	ND	ND	ND	0.0329
SRB-76/77	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-78	ND	ND	ND	ND	ND	ND	ND	ND	ND
SRB-79	**12.0**	ND	**0.0795**	ND	ND	ND	ND	ND	ND
SRB-80	ND	ND	ND	ND	ND	ND	ND	ND	0.0383
SRB-81	ND	ND	ND	ND	ND	ND	ND	ND	0.0249
SRB-82	ND	ND	ND	ND	ND	0.0014	ND	ND	0.290
SRB-83	ND	ND	ND	ND	ND	ND	ND	ND	ND

italics = constituent exceeded holding time
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Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	Radon-222 (pCi/L)	Alpha (pCi/L)	Beta (pCi/L)	Ra-226 + Ra-228 (pCi/L)	Uranium (µg/L)	VOCs (µg/L)	*^{18} O ($^0/_{00}$)	* D ($^0/_{00}$)	Type of Chemistry
SRB-1	**-**	1.2	9.5	-	-	-	-	-	sodium-chloride
SRB-2	-	1.5	2.5	-	-	-	-	-	calcium-bicarbonate
SRB-3/3D	**433**	-	-	-	-	Yes	-	-	sodium-bicarbonate
SRB-4/4S	**-**	8.3	4.5	ND	-	-	-	-	mixed-bicarbonate
SRB-5/5D	-	ND	1.8	-	-	Yes	-	-	mixed-bicarbonate
SRB-6	-	1.9	ND	-	-	ND	-	-	calcium-bicarbonate
SRB-7	-	8.2	4.5	ND	-	ND	-	-	mixed-mixed
SRB-8/8D	-	ND	6.8	-	-	-	-	-	sodium-chloride
SRB-9	-	3.0	4.0	-	-	-	-	-	sodium-mixed
SRB-12	-	ND	1.8	-	-	ND	-	-	mixed-bicarbonate
SRB-13	-	ND	2.5	-	-	Yes	-	-	calcium-bicarbonate
SRB-14/14S	**-**	2.1	1.6	-	-	ND	-	-	mixed-bicarbonate
SRB-15/15D	**-**	ND	2.4	-	-	-	-	-	mixed-bicarbonate
SRB-16/16S/59	**-**	5.3	1.7	ND	3.4	-	-11.0	-79	calcium-bicarbonate
SRB-17	**-**	ND	1.6	-	-	-	-	-	magnesium-bicarbonate
SRB-18	-	1.8	3.9	-	-	ND	-	-	calcium-bicarbonate
SRB-19	-	ND	ND	-	-	ND	-	-	mixed-bicarbonate
SRB-19A	-	1.1	ND	-	-	-	-	-	calcium-bicarbonate
SRB-20/20D	-	ND	ND	-	-	ND	-	-	calcium-bicarbonate
SRB-21/21S	-	9.3	2.1	0.74	-	ND	-	-	sodium-bicarbonate
SRB-22	-	ND	ND	-	-	-	-	-	calcium-bicarbonate
SRB-23	-	ND	2.1	-	-	-	-	-	calcium-bicarbonate
SRB-24	-	3.1	2.0	-	-	ND	-	-	calcium-bicarbonate
SRB-25	-	8.8	5.8	ND	-	ND	-	-	calcium-bicarbonate
SRB-26/26D	-	**35**	13	0.29	**38**	ND	-	-	mixed-bicarbonate
SRB-27	-	**24**	4.7	ND	9.5	ND	-	-	calcium-bicarbonate
SRB-28/28D	-	**37**	12	ND	**32**	-	-	-	mixed-bicarbonate
SRB-29	-	12	2.7	ND	-	-	-	-	mixed-bicarbonate

LLD = Lower Limit of Detection
italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	Radon-222 (pCi/L)	Alpha (pCi/L)	Beta (pCi/L)	Ra-226 + Ra-228 (pCi/L)	Uranium (µg/L)	VOCs (µg/L)	$*^{18}$ O $(^{0}/_{00})$	$*$ D $(^{0}/_{00})$	Type of Chemistry
SRB-30	-	4.7	2.0	-	-	-	-	-	calcium-bicarbonate
SRB-31	-	ND	3.7	-	-	ND	-	-	calcium-bicarbonate
SRB-32/32S	-	1.5	5.7	-	-	-	-	-	sodium-mixed
SRB-33	-	8.0	5.5	ND	-	ND	-	-	mixed-bicarbonate
SRB-34	-	3.0	2.9	-	-	-	-	-	mixed-bicarbonate
SRB-35	-	6.5	5.5	ND	-	-	-	-	calcium-sulfate
SRB-36	-	ND	2.0	-	-	-	-	-	mixed-bicarbonate
SRB-37	-	1.5	ND	-	-	-	-	-	calcium-bicarbonate
SRB-39	-	2.0	ND	-	-	ND	-	-	calcium-bicarbonate
SRB-40	-	4.9	3.0	-	-	-	-	-	mixed-bicarbonate
SRB-41	**3,146**	**17**	8.3	ND	16	Yes	-	-	sodium-bicarbonate
SRB-42a	**2,167**	4.9	3.1	-	-	Yes	-	-	sodium-bicarbonate
SRB-42b	-	-	-	-	-	-	-10.6	-74	calcium-bicarbonate
SRB-43	-	-	-	-	-	-	-11.3	-80	mixed-bicarbonate
SRB-44	105	3.6	-	-	ND	-	-10.4	-74	mixed-bicarbonate
SRB-45	-	-	-	-	-	-	-11.1	-79	mixed-bicarbonate
SRB-46	-	-	-	-	-	-	-11.4	-80	mixed-bicarbonate
SRB-47	282	-	-	-	-	-	-10.9	-76	calcium-bicarbonate
SRB-48	-	-	-	-	-	-	-10.5	-72	calcium-bicarbonate
SRB-49	-	-	-	-	-	-	-9.5	-66	calcium-bicarbonate
SRB-50	-	-	-	-	-	-	-10.5	-72	mixed-bicarbonate
SRB-51/52	**429**	ND	-	-	ND	-	-10.35	-70.5	calcium-bicarbonate
SRB-53	-	-	-	-	-	-	-11.2	-78	calcium-bicarbonate
SRB-54	-	-	-	-	-	-	-9.7	-68	calcium-bicarbonate
SRB-55	178	0.5	-	-	ND	-	-11.1	-75	calcium-bicarbonate
SRB-56	-	-	-	-	-	-	-11.0	-75	calcium-bicarbonate
SRB-57/58	-	1.1	-	-	ND	-	-10.3	-72	calcium-bicarbonate
SRB-61	-	-	-	-	-	-	-10.5	-75	calcium-bicarbonate

LLD = Lower Limit of Detection
italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Salt River Basin, 2001-2015-Continued

Site #	Radon-222 (pCi/L)	Alpha (pCi/L)	Beta (pCi/L)	Ra-226 + Ra-228 (pCi/L)	Uranium (µg/L)	VOCs (µg/L)	*^{18} O ($^0/_{00}$)	* D ($^0/_{00}$)	Type of Chemistry
SRB-62	-	0.9	-	-	ND	-	-10.7	-78	calcium-bicarbonate
SRB-63	-	-	-	-	-	-	-4.8	-50	magnesium-bicarbonate
SRB-64	**-**	-	-	-	-	-	-10.7	-78	calcium-bicarbonate
SRB-65	**-**	ND	-	-	7.8	-	-10.1	-73	calcium-bicarbonate
SRB-66/67	**-**	ND	-	-	5.2	-	-10.6	-76	calcium-bicarbonate
SRB-68	**-**	ND	-	-	1.7	-	-8.0	-67	calcium-bicarbonate
SRB-69	**2967**	ND	-	-	0.9	-	-9.9	-72	calcium-bicarbonate
SRB-70	-	-	-	-	-	-	-10.7	-74	mixed-bicarbonate
SRB-71	-	2.1	-	-	4.2	-	-8.2	-65	mixed-bicarbonate
SRB-73	**342**	ND	-	-	3.5	-	-10.6	-73	mixed-bicarbonate
SRB-74	**554**	ND	-	-	6.9	-	-9.3	-67	mixed-bicarbonate
SRB-75	**-**	-	-	-	-	-	-8.7	-62	calcium-chloride
SRB-76/77	**946**	0.8	-	-	12.4	-	-9.3	-68	sodium-bicarbonate
SRB-78	52.2	ND	-	-	0.8	-	-11.3	-76	calcium-bicarbonate
SRB-79	-	-	-	-	-	-	-9.6	-68.3	calcium-mixed
SRB-80	-	1.6	-	-	2.3	-	-10.1	-73.8	mixed-bicarbonate
SRB-81	**344.5**	1.6	-	-	2.2	-	-10.5	-74.3	calcium-bicarbonate
SRB-82	-	0.4	-	-	**33.5**	-	-8.6	-62.7	mixed-bicarbonate
SRB-83	**458**	0.4	-	-	2.0	-	-9.0	-67.2	sodium-chloride

LLD = Lower Limit of Detection
italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

VOC notes
SRB-5 chloroform 6.9 methylene chloride – 42 ug
SRB-13 – bromomethane – present
SRB-41 – chloromethane 4.2 ug/L
SRB-42 – chloromethane 1.4 ug/L

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